

**DEVELOPING AN INTEGRATED PREVENTIVE FRAMEWORK FOR
CONSTRUCTION WORKERS EXPOSED TO SILICA DUST AND
CHEMICAL IRRITANTS IN ZAMBIA.**

By

PRISCA TENTE

**A Thesis submitted to the University of Zambia in fulfilment of the
requirements for the Degree of Doctor of Philosophy in Construction
Management**

THE UNIVERSITY OF ZAMBIA
LUSAKA

2023

COPYRIGHT

© 2023, Prisca Tente

All rights reserved. No part of this thesis may be reproduced or stored in any form or by any means without prior permission in writing from the author or the University of Zambia.

DECLARATION

I, **Prisca Tente** hereby declare that the work presented in this thesis is a result of my research work and that it has not previously been submitted for a degree, diploma or other qualification at this or another University.



20 March 2023

Signature

Date

Supervisor: Erastus Mwanaumo, *PhD Eng, FCIQB, PrCPM, REng, MEIZ, MIOZ*

Signature

Date

CERTIFICATE OF APPROVAL

This thesis of **Prisca Tente** has been approved as fulfilling the requirements for the award of the **Doctor of Philosophy** Degree in **Construction Management** by the University of Zambia.

Examiners' Name	Signatures	Date
Professor Innocent Musonda External Examiner	_____	_____
Dr Bupe G Mwanza Internal Examiner	_____	_____
Dr Mwelwa Mambwe Internal Examiner	_____	_____
Dr Michael Mulenga Chairperson – Board of Examiners	_____	_____

ABSTRACT

Construction industry is key to the world economies in both developed and developing nations. However, construction works could bring hazards such as silica dust and chemical irritants to site personnel. Silica dust and chemical irritants are produced from activities such as demolition, drilling, concrete mixing, brick and concrete block cutting, sawing, tile cutting, painting and grading. Silica dust can cause respiratory diseases such as chronic obstructive pulmonary disease, renal disease, lung cancer and silicosis. Chemicals can cause skin diseases such as dermatitis and eczema. The effects of respiratory and skin diseases are devastating to the workers and in turn affect the cost of projects in terms of medical bills and lost man-hours. The strategies planned by Zambia in its quest to be a middle-income country by 2030 has resulted in an increase in construction projects. There is a high likelihood of an increase in the generation of dust and possible exposure to silica dust and chemical irritants. Several studies have shown a high silica dust and chemical irritant levels and high prevalence of symptoms of respiratory and skin diseases. Nevertheless, construction players are hesitant to adhere to Occupational Safety and Health Laws. Also, it is not known whether silica dust levels experienced by Zambian construction workers were above $0.05\text{mg}/\text{m}^3$. Therefore, the staple silica dust and chemical irritant hazards have to be mitigated. The aim of this study was to establish a preventive framework that promotes reduction of exposure to silica dust and chemical irritants. The Case Study- Mixed Method design involving a road construction and a building projects was used. Qualitative and quantitative methods were used simultaneously. Bricklayers, carpenters, batchers, tilers, demolition workers, painters, road construction workers and handymen were purposively sampled. The sample size was established at 10% of the estimated population of 1, 012. A questionnaire survey was conducted on 100 workers among which observations and photographs were randomly done. The Methods of Determination of Hazardous Substances (MDHS14/4) through gravimetric weighing of respirable dust samples and silica dust using MDHS101/2 through X-ray diffraction (XRD) were used for sampling and analysis. Fifteen personal air samples were taken during work activity for 8hr-Time Weighted Average. Quantitative data was analysed using descriptive and inferential statistics. Pearson Chi-square and degree of freedom were used to test the degree of association between the independent and dependent variables. The level of significance of $p < 0.05$ and confidence interval of 95% were considered as statistically significant. Qualitative data was analysed using constant comparative method. Results showed that chemical irritant exposure levels were high and silica dust exposure levels were higher than both local and international Occupational Safety Health Administration Permissible Exposure Limit ($0.05\text{mg}/\text{m}^3$). There was a high prevalence of symptoms of respiratory and skin diseases. Further, the controls which were used on site were inadequate. Therefore, an integrated preventive framework was developed to reduce exposure to silica dust and chemical irritants and eventually prevent respiratory and skin diseases to protect the workers and safeguard the projects. The study is in line with the Sustainable Development Goal (SDG) number three of achieving good health and well-being by 2023 through reducing the number of deaths and illnesses caused by hazardous chemical and air pollution and contamination. The findings and recommendations would serve as part of the guide policy formulation in Zambia.

Keywords: Exposures, Chemical irritants, Construction personnel, Prevention, Silica dust, Zambia.

DEDICATION

This work is dedicated to my late father Mr. Linus Mushibwe Tente and my mother Teresa Chibiliti Tente. To my husband Saviour KM Chanda, Mariateresa Tente Chanda my daughter and my late son baby Chisumino Chanda (who was my inspiration during my PhD journey as we were expecting him).

ACKNOWLEDGEMENTS

I thank God for His mercy and unfailing love as He walked with me throughout my research in thin and thick. God healed me and my family when we lost our son, baby Chisumino during my study journey. God has been faithful through the years.

I am grateful to my supervisor, Dr Erastus Mwanaumo for ensuring that I was on my feet to do my research and for his commitment to his guiding work. He did not only guide me academically, but also gave me emotional and morale support in my ups and downs.

I appreciate my beloved husband Saviour KM Chanda and daughter Mariateresa, for their love and support. For braving my absence from them, I love them dearly.

I am grateful to our late son Chisumino Chanda for the moments we spent together, mother and baby deep connection and holy moments. It was amazing that we journeyed together from data collection to thesis writing. Chisumino was my everyday motivation in my PhD journey.

Thanks to my late father for being my inspiration in my life. He believed I could do anything that is possible to a person.

I appreciate my mother Teresa Chibiliti Tente, my brothers (Boniface Kaloba Tente and Evans Mulongwe Tente) and sisters (Monica Mwansa Munthali, Lucy Chibesa Tente, Sr Catherine Mwewa Tente, Marjory Mushibwe Tente and Mary Tente Suzah) for their love, prayers and encouragements in my ups and downs, and for standing by me all my life.

Many thanks to all the research participants for their time and commitment. I am grateful to the management for the two sites I used for my case studies for their permission.

I recognise the help from the University of Zambia staff especially the Civil and Environmental department, school of engineering and DRGS. I also thank the construction stakeholder experts who helped in the framework model validation.

My fellow PhD candidates were instrumental in my journey as we encouraged each other and held each other's hand in support and confidence that we could make it. We shared knowledge.

To my workmates, colleagues, church-mates and my true friends who have been my cheer groups in the background giving me morale support and praying for me, I am thankful.

TABLE OF CONTENTS

COPYRIGHT	i
DECLARATION	ii
CERTIFICATE OF APPROVAL	iii
ABSTRACT.....	iv
DEDICATION	v
ACKNOWLEDGEMENTS	vi
LIST OF TABLES	xiii
LIST OF FIGURES	xv
LIST OF ACRONYMS	xvii
DEFINITION OF TERMS.....	xviii
CHAPTER 1: INTRODUCTION	1
1.1 Background of the Research.....	1
1.2 Research Problem.....	4
1.3 Purpose of the Research	7
1.4 Aim.....	8
1.5 Objectives.....	8
1.6 Research Questions	9
1.6 Summary of the Research Methodology	9
1.6.1 Secondary Data Source	10
1.6.2 Experimental Data.....	10
1.6.2 Questionnaire Survey	11
1.6.4 Observation	12
1.6.5 Data Analysis	12
1.6.5 Research Ethics	13
1.6.6 Bias.....	13
1.6.7 Validity.....	13

1.6.8	Reliability	13
1.7	Application of the Research/Significance	14
1.8	Limitation of the Research	14
1.9	Organisation of the Thesis.....	15
CHAPTER 2: LITERATURE REVIEW		17
2.1	Introduction	17
2.2	Research Legal Frameworks on Occupational Health and Safety	17
2.2.1	International Legal Frameworks	18
2.2.2	Zambian Legal Frameworks	19
2.3	Dust and Silica Dust Hazard	22
2.3.1	Silica Dust Exposure Levels in Construction	23
2.3.2	Prevalence of Symptoms of Respirable Disease in Construction	25
2.4	Chemical Irritants in Construction	26
2.4.2	Prevalence of Symptoms of Skin Disease in Construction.....	27
2.5	Silica Dust and Chemical Irritants Controls in Construction	29
2.5.1	Elimination method.....	29
2.5.2	Substitution method	29
2.5.3	Engineering control.....	30
2.5.4	Administrative Controls	31
2.5.5	Personal protective equipment (PPE).....	32
2.5	Frameworks	34
2.5.1	Framework for Program Evaluation.....	34
2.5.2	Spectrum of Prevention Framework	36
2.5.3	Strategic Prevention Framework (SPF)	38
2.5.4	Development of the Proposed Integrated Framework for the study	39
2.6	Critique of the Reviewed Literature	40
2.7	Contribution of the research to Literature	41

2.8	Theoretic Framework of the Study.....	55
2.8.1	Theory of Work Adjustment.....	55
2.8.2	Domino Safety Theory.....	56
2.8.3	Integration of Theory of Work Adjustment and Domino Safety Theory	57
2.9	Conceptual Framework of the Study.....	58
2.10	Hypotheses of the Research.....	60
2.11	Summary.....	62
CHAPTER 3: METHODOLOGY.....		63
3.1	Introduction.....	63
3.2	Research Paradigms.....	63
3.2.1	Ontology.....	63
3.2.2	Epistemology.....	64
3.3	Methodology.....	65
3.3.1	Research Design.....	65
3.3.3	Population.....	67
3.3.4	Sampling.....	67
3.3.5	Ethical Considerations.....	69
3.4	Research Methods.....	70
3.4.1	Data Collection Techniques and Instruments.....	70
3.4.2	Bias.....	73
3.4.3	Validity.....	73
3.4.4	Reliability.....	74
3.4.5	Data Analysis and Interpretation.....	75
3.5	Summary.....	77
CHAPTER 4: RESULTS PRESENTATION.....		79
4.1	Introduction.....	79

4.2	Profile of Respondents	79
4.3	Silica Dust Sampling Results	79
4.3.1	Silica and Respirable Dust Exposure Levels	80
4.4	Questionnaire Results	83
4.4.1	Silica Dust Exposure Levels	83
4.4.2	Prevalence of Symptoms of Respirable Diseases	86
4.4.3	Chemical Irritants Exposure Levels	86
4.4.4	Levels and Period of Exposure to Chemical Irritants in relation to Symptoms of Skin Diseases.....	88
4.4.5	Prevalence of Symptoms of Skin Diseases	91
4.4.6	Controls Used on Sites for Silica Dust Exposure Reduction	93
4.4.7	Silica Dust Controls and Prevalence of Symptoms of Respirable Diseases.....	95
4.4.8	Controls Used on Sites for Chemical Irritants Exposure Reduction.	96
4.5	Observation and Photographs Results	98
4.5.1	Dust Exposures on Sites.....	98
4.5.2	Chemical Irritants Exposures on Sites	104
4.5.3	Symptoms of Skin Diseases	107
4.5.4	Controls Used on Sites for dust Exposure Reduction	111
4.5.5	Controls Used on Sites for Chemical Irritants Exposure Reduction.....	113
4.5.6	Provision of Adequate PPE.....	115
4.6	Summary	117
CHAPTER 5: DISCUSSION OF RESULTS		118
5.1	Introduction	118
5.2	Silica Exposure Levels in Relation to Occupational Safety Health Administration Permissible Exposure Limit (0.05mg/m ³).....	118

5.3	Dust Levels in Relation to Prevalence of Symptoms of Respiratory Diseases	122
5.4	Levels and Period of Exposure to Chemical Irritants in Relation to Symptoms of Skin Diseases	123
5.5	Controls Used on Sites for Silica Dust in Relation to Symptoms of Respiratory Diseases	125
CHAPTER 6: PREVENTIVE FRAME WORK DEVELOPMENT		132
6.1	Introduction	132
6.2	The Importance of the Framework	132
6.3	How the Framework will Function	133
6.3.2	Enforcement Prevention Stage	138
6.3.3	Execution Prevention Stage	141
6.4	Framework Model Processes.....	143
6.5	The Roles of Construction Stakeholders	144
6.5.1	The Role of the Client	145
6.5.2	The Role of the Project Managers.....	146
6.5.3	The Role of the Engineers.....	147
6.5.4	The Role of the Health and Safety Agent	147
6.5.5	The Role of the Contractor, subcontractors and suppliers	148
6.5.6	The Role of Government and its agencies	148
6.5.7	The Role of Health and Safety Officer and Committees	150
6.5.8	The Role of Skilled and other Personnel.....	151
6.5.9	The Role of the Community Representatives	151
6.6	Framework Validation Process	152
6.7	Validation Results and Discussion	153
6.7.1	Profile of Framework Model Validation Respondents	153
6.7.2	Framework Model Characteristics Results	156
6.7.3	Framework Model Process Durations.....	157

6.8	Summary	162
CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS		163
7.1	Introduction	163
7.2	Research Summary	163
7.3	How Research Objectives Were Achieved	163
7.3.1	Evaluation of Research Objective Number One	164
7.3.2	Evaluation of Research Objective Number Two	165
7.3.3	Evaluation of Research Objective Number Three	165
7.3.3	Evaluation of Research Objective Number Four	166
7.3.5	Evaluation of Research Objective Number Five.....	167
7.4	Research Contribution to the body of Knowledge	169
7.5	Research Implications	169
7.6	Research Recommendations.....	169
7.7	Limitation of the Research	171
7.8	Recommendations for Further Research	171
REFERENCES.....		173
APPENDICES		190
A1:	Questionnaire Survey Cover Letter.....	190
A2:	QUESTIONNAIRE	191
A3:	Observation Schedule.....	197
A4:	Framework Validation Questionnaire Cover Letter.....	198
A5:	Validation Questionnaire	199

LIST OF TABLES

Table 2.1: Silica Exposure Reduction by Some Authors.....	34
Table 2.2: Literature Review Matrix.....	42
Table 2.3: Application of Domino Theory in this Research.....	57
Table 3.1: Cronbach's Alpha Rule of Thumb.....	74
Table 3.2: 5 Point Likert Scale and its interpretation.....	77
Table 4.1: Exposure Levels for Respirable Dust and Respirable Crystalline Silica Dust.....	80
Table 4.2: Job Titles in relation to Respirable Crystalline Silica Dust Exposure Levels.....	82
Table 4.3: Job Titles in relation to Respirable Dust Exposure Levels.....	82
Table 4.4: One-Sample Test for RCS Dust Using OSHA-PEL of $0.05\text{mg}/\text{m}^3$	82
Table 4.5: One-Sample Test for RD Dust Using OSHA-PEL of $5\text{mg}/\text{m}^3$	83
Table 4.6: Independent Sample Test for Levels of Dust and Type of Construction.....	84
Table 4.7: Profile of Respondents in relation to the Levels of Dust Exposures.....	85
Table 4.8: Comparison of Means Between Dust Levels and Symptoms of Respirable Diseases.....	85
Table 4.9: Cross Tabulation of Dust Levels against Symptoms of Respirable Diseases.....	86
Table 4.10: Profile of Respondents in relation to Symptoms of Respirable Diseases.....	87
Table 4.11: Independent Sample Test for Levels of Exposure to Chemical Irritants and Type of Construction.....	88
Table 4.12: Profile of Respondents in relation to the Levels of Exposure to Chemical Irritants.....	89
Table 4.13: Comparison of Means Between Exposure Levels and Symptoms of Skin Diseases.....	90
Table 4.14: Cross Tabulation Between Exposure Levels and Symptoms of Skin Diseases.....	90
Table 4.15: Cross Tabulation Between Period of Exposure and Symptoms of Skin Diseases.....	90
Table 4.16: Profile of Respondents in relation to Symptoms of Skin Diseases.....	92
Table 4.17: Dust Controls in relation to Symptoms of Respirable Disease.....	97

Table 4.18: Chemical Irritant Controls in relation to Symptoms of Skin Diseases...	83
Table 4.19: Correlation between Prevalence of Symptoms of Skin Diseases and Controls.....	98
Table 5.1: Summary of Findings in line with Objectives.....	130
Table 6.1: Construction Stakeholder Involvement in the Preventive Framework...	136
Table 6.2: Validity of Framework Model Validation Results.....	155
Table 6.3: Framework Model Characteristics One-Sample Test Results.....	156
Table 6.4: Framework Model Process Duration One-Sample Test Results.....	158
Table 6.5: Assessment of the Integrated Framework Model.....	159
Table 6.6: Frequency Table for the Overall Rating of the Framework Model.....	161
Table 6.7: Overall Rating of the Framework Model.....	161

LIST OF FIGURES

Figure 2.1: High-Efficiency Particulate Arrestance (HEPA)-vacuum system (a) and Permanent Installations Typical of Large Industrial Facilities.....	32
Figure 2.2: Theoretical Framework.....	58
Figure 2.3: Conceptual Framework.....	60
Figure 3.1: Research Design.....	66
Figure 4.1: Prevalence of Symptoms of Respirable Diseases.....	86
Figure 4.2: Prevalence of Symptoms of Skin Diseases.....	91
Figure 4.3: Frequency of Symptom of Skin Diseases.....	93
Figure 4.4: Duration of Symptoms of Skin Diseases.....	93
Figure 4.5: Dust Controls Used on Sites.....	95
Figure 4.6: Reasons for Wearing Dust Masks.....	95
Figure 4.7: Picture showing dust exposure during offloading of gravel.....	99
Figure 4.8: Picture depicting dust exposure during loading of spoil.....	99
Figure 4.9: Picture showing dust exposure during dry concrete grinding.....	100
Figure 4.10: Picture showing workers loading quarry dust for batching.....	101
Figure 4.11: Picture showing dust exposure during sweeping.....	102
Figure 4.12: Picture showing cement dust exposure during dry mixing.....	103
Figure 4.13: Picture showing dust exposure during demolition and loading of rubble.....	103
Figure 4.14: Picture showing exposure to wet concrete on the road project.....	105
Figure 4.15: Picture presenting exposure to bitumen on the road project.....	105
Figure 4.16: Picture showing exposure to wet concrete on the building project....	106

Figure 4.17: Picture presenting exposure to wet mortar during building.....	106
Figure 4.18: Picture showing exposure to wet mortar during plastering.....	107
Figure 4.19: Picture showing exposure to paint during painting.....	108
Figure 4.20: Picture showing hands with fissure.....	108
Figure 4.21: Picture showing dry scaly hands.....	109
Figure 4.22: Picture showing wet scaly and hands.....	109
Figure 4.23: Picture showing vesicles on hands.....	110
Figure 4.24: Picture showing red bumps.....	110
Figure 4.25: Picture showing the use of cutter with water on the road project...	111
Figure 4.26: Picture showing dust control using water on the road project.....	112
Figure 4.27: Picture showing a worker wearing a face mask while working.....	112
Figure 4.28: Picture showing a worker wearing a dust mask while working.....	113
Figure 4.29: Picture showing the use of cotton-PVC gloves.....	114
Figure 4.30: Picture showing the use of PVC gloves.....	114
Figure 4.31: Picture showing some of the workers in gumboots.....	115
Figure 4.32: Picture showing exposure to wet concrete without PPE on a building project.....	116
Figure 4.33: Picture showing wrong PPE for working with wet concrete.....	116
Figure 4.34: Picture showing a worker without adequate PPE.....	117
Figure 6.1: Integrated Preventive Framework Model.....	135
Figure 6.2: Respondents' Type of Construction Stakeholder Group.....	154

LIST OF ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienist
CDC	Centers for Diseases Control and Prevention
HSE	Health Safety Executive
LEV	Local Exhaust Ventilation
LOD	Limit of Detection
LOQ	Limit of Quantification
MAC	Maximum Allowable Concentration
MDHS	Methods of Determination of Hazardous Substances
NASREC	Natural and Applied Sciences Research Ethics Committee
OEL	Occupational Exposure Limit
OHSA	Occupational Health and Safety Act
OHSI	Occupational Health and Safety Institute
OSHA	Occupational Safety Health Administration
NAREC	Natural and Applied Sciences Research Ethics Committee
NHLS	National Health Laboratory Services
NIOH	National Institute for Occupational Health
NIOSH	National Institute for Occupational Health and Safety
PELs	Permissible Exposure Limits
PVC	Polyvinyl Chloride
RCS	Respirable Crystalline Silica
RD	Respirable Dust
RDA	Road Development Agency
RELs	Recommended Exposure Limits
RPE	Respirable Personal Equipment
SPSS	Statistical Package for Social Science
TLV	Threshold Limit Value
TWA	Total Weighted Averaged
WELs	Workplace Exposure Limits
XRD	X-ray Diffraction

DEFINITION OF TERMS

Coughing is the defensive reflex action that helps the clearance of secretions and aspiration of foreign particles from the airways. (De Blasio et al., 2011).

Crystalline Silica dust is made up of small particles that become airborne during work activities with materials that contain crystalline silica (Thomas and Kelley, 2010).

Exposure is defined as the concentration of airborne occupational crystalline silica dust measured in the workers' personal breathing environment (Yassin et al., 2005).

Framework is the structure of ideas, information and principles (Cambridge Dictionary, 2022).

Health hazards are substance or conditions that may cause health impacts or loss of life (Rovins et al., 2015).

Integrated is the combining of two or more things to improve the effectiveness.

Shortness of breath is a subjective awareness of the sensation of uncomfortable breathing usually as a result of social, physiological or pathological factors (Coccia et al., 2016).

Silicosis may be defined as the disease resulting from chronic occupational exposure to silica dust.

Wheezing is breathing with a whistling or ratting sound in the chest (Cambridge Dictionary, 2022).

Permissible Exposure limit PEL is the level of exposure established as the highest level of exposure an employee may be exposed to without incurring the risk of adverse health effects (OSHA, 2017).

CHAPTER 1: INTRODUCTION

1.1 Background of the Research

Construction industry is key to the economies of the world through infrastructure development both in developed and developing countries. However, rapid urbanization and industrialization affect social, cultural and health in construction worldwide (Mashqoor et al.,2017). Construction works bring about hazards and risks that cause ill health and accidents that harm or claim lives of construction site personnel (Tente and Muya, 2014). The workers perform activities such as mixing, pouring and spreading concrete, laying of asphalt, gravelling, grinding, cutting and other construction activities. These activities produce dust that contain Respirable Crystalline Silica (RCS) or silica dust that when inhaled, for a period of time can cause symptoms of respiratory diseases such as silicosis (Normohammadi et al., 2016). Moreover, during construction activities, chemicals may come in contact with the workers' skin and may cause symptoms of skin diseases such as dermatitis (Mashqoor et al., 2017).

The RCS is part of dust, which is generated from many processes of different industries of the world economies such as agriculture, mining, construction and manufacturing industries. During land tilling, agriculture dust is generated (Swanepoel, 2012). In the mining industry, dust is generated from crushing, extraction, drilling and stone breaking. Gholami et al. (2012) found the total dust concentration of $94.3\text{mg}/\text{m}^3$ in the Iron-stone mine in Iran. In the construction industry, dust is generated from activities such as breaking, cutting and crushing. The total dust concentration in construction was $13.37\text{mg}/\text{m}^3$ for demolition workers (Normohammadi et al., 2016). Dust is also generated in the dental laboratory from sanding and sand blasting through process of porcelain and polishing (Kim et al., 2002).

Silica is a primary hazard in construction which is contained in commonly used construction materials such as concrete and sand (Flanagan et al., 2003). However, it has not been well characterized because of frequent turnover of personnel and continually changing workplaces, tasks and environmental conditions (Flanagan et al., 2003). It has been established that construction industry still records high silica exposure levels (Bello et al., 2019). This may be because the exposure to dust is part

of activities from excavation of foundation to cleaning up site after completion of a project (Lumens and Spee, 2001). In highway maintenance, road construction and repair workers are potentially exposed to silica dust during sawing, breaking and grinding concrete and other materials that contain silica (Valiante et al., 2004). According to the Health and Safety Executive (HSE, 2012), exposure to RCS can lead to occupational diseases such as chronic obstructive pulmonary disease, renal disease, tuberculosis, lung cancer and silicosis. Among the respiratory diseases, silicosis may take long to develop depending on exposure levels and its symptoms are; shortness of breath, wheezing, chest tightness and coughing (Valiante et al., 2004).

Exposure to tiny particles of airborne silica, occurs mainly in industrial and occupational settings. In order to regulate exposure to silica dust, there are international Permissible Exposure Limits (PELs) that have been established for different industries. According to Occupational Safety and Health Administration (OSHA), the PEL is the level of exposure established as the highest level of exposure an employee may be exposed to without incurring the risk of adverse health effects (OSHA, 2017). The silica dust OSHA PEL for the construction industry is $0.05\text{mg}/\text{m}^3$ and the action level of $0.025\text{mg}/\text{m}^3$, in 8-hour Total Weighted Average (TWA). The OSHA PEL for respirable dust is $5\text{mg}/\text{m}^3$ and total dust is $15\text{mg}/\text{m}^3$. The Workplace Exposure Limits (WELs) for HSE for silica dust is $0.1\text{mg}/\text{m}^3$, respirable dust is $4\text{mg}/\text{m}^3$ and total dust is $10\text{mg}/\text{m}^3$, in 8-hour TWA (HSE, 2020). Zambia, however, has no exposure limits for respirable dust and silica dust. What is regulated is general dust (total dust) which has a legal limit of $1.75\text{mg}/\text{m}^3$ (Hayumbu et al., 2008). Hence, the OSHA PELs have been adopted in this study because they are similar to other exposure limits for organisations in different countries. Moreover, it is clearly stated that anything above these limits can cause health risks unlike the HSE WELs which are used as just triggers.

Several industries have recorded high silica concentrations which were above the PELs. In the study by Kim et al. (2002), silica concentration in the dental laboratory dust was about $0.0509\text{mg}/\text{m}^3$ which was within the PEL in Korea ($0.05\text{mg}/\text{m}^3$). Gholami et al. (2012) found silica content of 15.5% which was higher than the standard in the iron-stone mine. In the glass industry, Dehghan and Razavizadeh

(1996) also found silica content of 9.5 times higher than OSHA PEL. In a study by Mohamed et al. (2018), the silica content was 50% in the occupational dust in selected industries in Egypt. Swanepoel, (2012) found that in the agriculture dust, silica content ranged from 0.5 to 94.4% in the three farms that was sampled. In Iran, in the study by Normohammadi et al. (2016), the concentration of silica in building demolition dust was $0.138\text{mg}/\text{m}^3$ which was equally more than the PEL of $0.05\text{mg}/\text{m}^3$.

In Zambia, Nsunge (2019) found that the respirable dust for road construction workers was $1.768\text{mg}/\text{m}^3$ which was slightly above the Zambian legal limit for dust of $1.75\text{mg}/\text{m}^3$. Hayumbu et al. (2008) conducted a study in the mining sector and found that the mean respirable dust in the Nkana and Mufulira Copper Mines was $0.868\text{mg}/\text{m}^3$ and $0.992\text{mg}/\text{m}^3$ while silica dust was $0.143\text{mg}/\text{m}^3$ and $0.060\text{mg}/\text{m}^3$ respectively. The silica dust in both Nkana and Mufulira Copper Mines were above the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of $0.050\text{mg}/\text{m}^3$ for respirable crystalline silica. Despite these findings, silica dust was not considered in the monitoring of dust in the mining industry in Zambia. The findings suggest that more miners were exposed to silica dust. There has not been any research in the construction industry in Zambia on silica dust exposure despite the fact that construction and mining have similar dust and silica dust generating activities such as breaking, drilling and quarrying.

Another hazardous material which is a staple material in construction for concrete is cement. It contains Calcium Oxide (CaO) which reacts with water (H_2O) to form calcium hydroxide which is a very strong irritant to the skin (Avnstorp, 1992). Moreover, cement contains potassium dichromate which causes skin diseases such as dermatitis (Sharma et al., 2014). Dermatitis is one of recognized work-related diseases with high annual cost to society (Skoet et al., 2004) and may result in emotional and physical morbidity (Handa, et al., 2012). The common symptoms of skin diseases are itching, redness, thickened, fissured and scaly skin and lesions (Bourke et al., 2009).

The construction industry in Zambia is not unexceptional to silica dust and chemical irritants hazards. As Zambia aspires to be a prosperous middle-income country by

2030, there are planned strategies in the 7 National Development Plan 2017-2021 in the construction industry. Under the Economic Diversification and Job Creation, Outcome number six, government planned to prioritise construction and rehabilitation of railways, aviation infrastructure, road network and marine and inland waterways. This entails increase in construction projects and job creation in the industry. There is a likelihood of an increase in the generation of dust and possible contact to silica dust and chemical irritants. Construction companies, however, are hesitant to adhere to Occupational Safety and Health Laws (Tente, 2016). There has been no study to establish a preventive framework to reduce exposure to silica dust and chemical irritants to safeguard the construction workers and also to reduce the effects of silica dust and chemical irritants on the overall construction projects.

1.2 Research Problem

The strategies planned by Zambia in its quest to be a middle-income country by 2030 has resulted in an increase in construction projects. This means that more personnel are being employed and more materials and chemicals are used during the execution of the projects. The exposure to silica dust and chemicals may be increased as activities such as jack hammering, rock drilling, concrete mixing, sanding, brick and concrete block cutting and sawing, clearing and grading, tile cutting and demolition are part and parcel of construction. Construction personnel who are specialised in such activities like bricklayers, batchers, tilers, carpenters, painters, road construction and demolition workers may be more exposed to silica dust and chemicals. Moreover, despite the increasing mechanization in construction and frequent use of precast concrete sections, contact with wet cement still occurs, especially in small jobs. Likewise, with the 20% subcontracting policy by the Zambian government through Road Development Agency (RDA) of all big project to local contractors (RDA, 2015), workers employed by subcontractors may be exposed to silica dust and chemical irritants. As a result, construction specialised personnel experience symptoms of respirable and skin diseases caused by exposures to silica dust and chemical irritants hazards (Tente, 2016).

Unfortunately, efforts to protect the construction personnel are inadequate as safety and health guidelines are less strictly supervised in many developing countries including Zambia (Tente, 2016; Bhattarai et al., 2015). Zambia does not yet have a

national policy on occupational safety and health (International Labour Organisation-ILO, 2012). In addition, Zambia has no effective preventive framework to protect the construction workers from exposure to silica dust and chemical irritant hazards.

Globally, the estimated number of workers who are exposed to silica dust and are 23 million workers in China, 11.5 million in India, 3.2 million in the European Union and 2.3 million in the United States (US) (Kreff et al., 2020). According to Shi et al. (2020) there were more than 20,000 reported incident cases of silicosis as in 2017 a result of exposure to silica dust (Shi et al., 2020). In the study by Bello et al. (2019), it was established that construction industry still records high silica exposure levels. According to the Institute of Occupational Medicine (IOM) in Europe, out of the 5.3 million workers who were exposed to silica dust, 75% were construction workers (IOM, 2011). Also in the report on National programme for the elimination of silicosis which was part eliminating silicosis in workplaces by 2030 in line with the International Labour Organisation (ILO) and the World Health Organisation's (WHO) Global Programme for the Elimination of Silicosis, silica dust was still a health concern. This was for both mining and non-mining industries like construction in Southern Africa (Motshelanoka, 2005).

In Zambia, a recent study by Nsunge (2019) revealed that respiratory symptoms were prevalent among the road construction workers due to dust exposures. The respirable dust concentration among road construction workers was $1.768\text{mg}/\text{m}^3$ which was above the Zambian legal limit for dust. The evidence of prevalence of respiratory symptoms and skin diseases in Zambia's construction industry (Nsunge, 2019; Tente, 2016) is an indication that workers are exposed to dust and chemical irritants that are harmful to them.

Moreover, despite having a lower total dust exposure legal limit ($1.75\text{mg}/\text{m}^3$) than OSHA PEL ($10\text{mg}/\text{m}^3$), Zambia had not yet set exposure limit for respirable and silica dust during the study period similar to some African countries like Nigeria (Gottesfeld, 2019; Hayumbu et al. (2008). This may have been because there was no institution or laboratories to measure and analyse respirable silica dust. Thus, in this study, OSHA PEL of $0.05\text{mg}/\text{m}^3$ for RCS and $5\text{mg}/\text{m}^3$ for respirable dust were

adopted. The PEL is the highest level of exposure an employee may be exposed to without incurring the risk of adverse health effects (OSHA, 2017). It was established to ensure that workers health is safeguarded. This means that all concentrations of respirable and silica dust above the PELs are harmful to the workers. The most dangerous part of dust which has lethal effects, is silica dust (Li et al., 2019). Hence the exposure to silica dust has to be mitigated.

Increase in construction projects in Zambia has resulted in increase in exposure to silica dust and chemical irritants that cause respiratory and skin diseases in specialised personnel. Several studies and reports have shown that construction industry records high silica dust levels and chemical irritants that pose as health hazards to the workers (Bello et al. 2019; Timmerman, 2017; Motshelanoka, 2005). The study by Nsunge (2019) showed 43% prevalence of symptoms of respiratory diseases. Tente (2016) reported 22% and 14% prevalence of respiratory and skin diseases in the construction industry in Zambia respectively. Symptoms of respiratory and skin diseases affect workers' health and may lead to death and negatively impact projects through lost man-hours, low productivity, hospital bills and compensations. It is not known whether the silica dust exposure levels in the construction industry in Zambia are above the OSHA PEL of $0.05\text{mg}/\text{m}^3$ as Nsunge (2019) only measured the respirable dust. Inhaling silica dust above $0.05\text{mg}/\text{m}^3$ causes respirable problems, when exposure is high or for long time, it leads to silicosis which has no known cure (Li et al., 2019; OSHA, 2017). There could be high silica dust exposure levels since the concentrations experience in the construction industry in Zambia are unknown. On the other hand, exposure to chemical irritants causes symptoms of skin diseases which are common in construction in Zambia (Tente, 2016). Reduction in exposure levels to silica dust and chemical irritants will lead to reduction of symptoms of respiratory and skin diseases, safeguard workers' health and improve production on the projects. Therefore, a study to establish a preventive framework to reduce exposures of silica dust and chemical irritants to safeguard workers' health and mitigate their effect on the construction projects is important.

Consequently, the **problem statement was**: as Zambia sets to become middle-income country by 2030, there has been an increase in the construction projects

which has resulted in increase in exposure to silica dust and chemicals that cause respiratory and skin diseases. The high global estimated number of workers exposed to silica dust and the high prevalence of silicosis especially in the construction industry, is a serious concern and requires solutions (Kreffft et al., 2020; Shi et al., 2020; Bello et al., 2019; IOM, 2011; Motshelanoka, 2005). Moreover, in Zambia, Nsunge (2019) reported 43% prevalence symptoms of respiratory diseases while Tente (2016) found 22% and 14% prevalence of respiratory and skin diseases respectively. The symptoms of respiratory and skin diseases affect workers' health and negatively impact projects through lost man-hours, low productivity, hospital bills and compensations. It is unknown if silica dust exposure levels experienced in construction industry were above OSHA PEL ($0.05\text{mg}/\text{m}^3$). It has been scientifically proved that silica dust concentration levels above $0.05\text{mg}/\text{m}^3$ affect worker's health. To the knowledge of the author, there has not been any study in the construction industry in Zambia which has been conducted to establish silica dust concentrations and to establish a preventive framework to reduce exposures of silica dust and chemical irritants to safeguard workers' health and mitigate their negative effect on the construction.

1.3 Purpose of the Research

The rationale for undertaking the study was to provide an integrated preventive framework for construction specialised personnel that can be used to reduce silica dust and chemical irritants exposure that leads to symptoms of respirable diseases and skin diseases. Recent study by Nsunge (2019) revealed that there was a prevalence of respiratory symptoms in the road construction. Moreover, in another research by Tente (2016) showed that the common occupational diseases in the construction industry in Zambia were lung diseases and skin diseases. According to data from Occupational Health and Safety Institute (OHSI) of Zambia, the diseases were as a result of exposure to dust and chemicals. The effects of respiratory and skin diseases symptoms are not only detrimental to the health of the workers but also affect construction projects as the results of loss of man-hours. The workers become ineffective on the project, thereby failing to meet construction schedules. However, silica dust and chemical hazards have received less attention despite their devastating effects in the construction industry in Zambia.

Furthermore, the existing Occupation Health and Safety Act (OHSA) of 2010 seemed not to adequately address the reduction of silica dust and chemical irritants exposure levels. This was evidenced by the findings by Tente (2016) that lung disease and skin diseases were the common occupational diseases in the construction industry in Zambia despite OHS Act of 2010 being in use. It is important to adequately reduce silica dust and chemical irritants exposure levels as means of prevention from respiratory and skin diseases to protect the workers. Moreover, in line with the Sustainable Development Goal number three of achieving good health and well-being by 2030, it is a requirement that a number of deaths and illnesses caused by hazardous chemical and air pollution and contamination are reduced. Consequently, the rationale for undertaking the study was to provide an integrated preventive framework that would help reduce silica dust and chemical irritants in construction in Zambia to safeguard specialised personnel's health and mitigate negative effects the hazards bring about on the projects.

1.4 Aim

The aim of the study is to develop an integrated preventive framework that can be used to reduce exposure to silica dust and chemical irritants for construction site personnel in Zambia.

1.5 Objectives

The specific objectives of the study were:

- i) To establish levels of silica dust construction specialised personnel were exposed to in relation to OSHA PEL ($0.05\text{mg}/\text{m}^3$).
- ii) To assess the dust levels in relation to the prevalence of symptoms of respiratory diseases.
- iii) To determine the levels and period of exposure to chemical irritants in relation to prevalence of symptoms of skin diseases for construction specialised personnel in Zambia.
- iv) To identify current existing controls for silica dust and chemical irritants in relation to prevalence of symptoms of respiratory and skin diseases.
- v) To develop an integrated preventive framework for specialised construction site personnel exposed to silica dust and chemical irritants.

- vi) To validate the developed integrated framework using construction stakeholders and experts.

1.6 Research Questions

The primary research question was; can an integrated preventive framework reduce exposure to silica dust and chemical irritants among specialised site construction personnel in Zambia? The secondary questions were;

- i) What were levels of silica dust construction specialised personnel were exposed to in relation to OSHA PEL(0.05mg/m³)?
- ii) How were the dust levels in relation to the prevalence of symptoms of respirable diseases?
- iii) Were the levels and period of exposure to chemical irritants related to prevalence of symptoms of skin diseases for construction specialised personnel in Zambia?
- iv) How were the existing controls for silica dust and chemical irritants in relation to prevalence to symptoms of respiratory and skin diseases?
- v) Could a preventive framework to reduce exposure to silica dust and chemical irritants in construction be developed?
- vi) Could a developed integrated framework be validated by construction stakeholders and experts?

1.6 Summary of the Research Methodology

To address the research aim which is to develop an integrated framework for construction skilled personnel exposed to silica dust and chemical irritants in Zambia, the Case Study-Mixed Method Convergent design was used. It involves the use of both qualitative and quantitative methods simultaneously. The process included collecting primary data and secondary data. The primary data was collected from experiments, questionnaire survey and observations. The secondary data was from the literature review on previous studies that are in line with the research objectives. Two case studies were used; a road and a building project. This was to get both experiences from both sectors as the activities and skilled are similar. Bricklayers, carpenters, batchers, tilers, demolition workers, painters, road construction workers and handymen were purposively sampled. Workers were identified by the help of site supervisors and the safety officers.

1.6.1 Secondary Data Source

The secondary data was collected from literature review on the previous studies on silica dust and chemical hazards, exposure levels, symptoms of respiratory and skin diseases, and controls in construction. The secondary data helped in setting the base for the study. Different sources were used to review literature such as books, articles, journals, conference proceedings, legal frameworks, guidelines, reports, theses and internet. The literature which was reviewed helped in examining the different methods of silica dust sampling and analysis that exist. Moreover, research methods of data collection and analysis which were used in previous studies similar to this research were reviewed. Literature review also aided in establishing a gap which this research seeks to fill.

The resulting theory that was used in this research was an integration of Domino Safety Theory and Theory of Work Adjustment. The review of literature informs the research theory and the basis for the design of the questionnaires. In addition, the relevant literature review gives an insight of both international and local research findings on the topic, However, few researches were conducted on both the silica dust and chemical irritants in one study. This is important because construction staple materials that contain silica become chemical hazards in their wet state and produce silica dust in their dry state during some construction activities. No research has been done in the construction industry in Zambia to address exposures and mitigating measures for both hazards and to specifically establish the silica dust concentration the workers are exposed to in relation to the OSHA PEL of $0.05\text{mg}/\text{m}^3$.

1.6.2 Experimental Data

The Methods of Determination of Hazardous Substances (MDHS14/4) through gravimetric weighing of respirable dust samples (HSE, 2014) and the RCS using MDHS101/2 (HSE, 2005) through X-ray diffraction (XRD) were used for sampling and analysis. The dust sampling media included a Casella Apex2 sampling pump which was attached to the employee's waist and connected through a tubing to a pre-weighted 25-mm, 5- μm pore size polyvinyl chloride (PVC) filter in a filter cassette. The experimental data from the dust sampling was collected during work activity for 8hr- TWA. The planned silica dust samples were 30 in total; 15 on the building

project and 15 on the road project. However, 15 samples were collected on the building project. The other 15 samples on the road project were not possible to collect because of flooding as road work activities were suspended. Silica dust measurements were limited to 30 samples because the silica dust sampling equipment and media were hired from National Institute for Occupational Health (NIOH) in South Africa as there was no facility to sample and analyse silica dust in Zambia at the time of the study. The sampling media was received late because of the importation customs clearances for both South Africa and Zambia. The 15 dust samples that were sampled on the building project were sent to back to South Africa to the laboratory for analysis at the National Institute for Occupational Health (NIOSH) a division of National Health Laboratory Services (NHLS).

1.6.2 Questionnaire Survey

The estimated study population for both building and road project sites was 1,012 workers. The sample size was established at 10% of the estimated population (Martínez-Mesa et al., 2016). Moreover, the sample size of 100 was selected using a conventional method and is justified by previous study that supports that the sample size of 45 and above is enough for construction-related research for the questionnaire survey (Fellows and Liu, 2008). In addition, the sample size was limited to 100 because of Covid-19 restrictions which led to downsizing the workforce on both the building and road projects as a directive preventive measure from Ministry of Health. Therefore, the sample size was $n=100$. Questionnaires were distributed to 100 workers who were purposively sampled. The 100 questionnaires were equally shared between a road and building projects to get experiences from both sectors.

The first phase questionnaire respondents were purposively sampled as guided by literature review of the specific workers who experience more exposure to silica dust and chemical irritants in the construction industry. These workers are bricklayers, carpenters, batchers, tilers, demolition workers, painters, road construction workers and their handymen. A simple random sampling was then used to administer an interview-based questionnaire among the purposively sampled. The questionnaire survey was interview based because some workers were not able to read and write especially the handymen. Moreover, the site management did not want the workers

to take a long break to attend to the questionnaires as both projects which were used for case studies were behind schedule. Therefore, an interview-based questionnaire was adopted because it was faster. The first phase of the questionnaire survey was to achieve the second, third and fourth objectives and research questions respectively.

The second phase of the questionnaire survey involved a 5-point Likert scale where strongly disagree was 1, disagree was 2, not sure was 3, agree was 4 and strongly agree was 5. The questionnaire was self-administered as this involved construction stakeholder experts who were academically clarified. The experts were purposively sampled for their expertise either in construction or occupation safety and health both from private and government institutions. The purpose of the second phase of the questionnaire survey was to help in the validation of the framework model and to achieve the fifth objective and research question.

1.6.4 Observation

The qualitative data was collected through overt observation using observation schedule and the camera for photographs. Observation method was used to validate the findings from experimental and the first phase questionnaire survey. In addition, it addresses all the objectives and research questions in one way or another. For example, the silica dust levels from experimental data in section 4.3.1 were observed in terms of dust levels as presented in section 4.5.1 in form of photographs which were captured by a camera.

1.6.5 Data Analysis

The quantitative data was captured in excel and analysed using Statistical Package for Social Science (SPSS) using IBM SPSS version 1.0.0.45 through descriptive and inferential statistics. The experimental results were further analysed quantitatively using SPSS to test the first hypothesis. The questionnaire survey data from both the first and second phases were also analysed in SPSS to test hypotheses numbers two, three and four. The qualitative data from observations was analysed through the constant comparative method with the help of photographs that were captured during observation. The overall results were compared and interpreted convergently or divergently to draw conclusions that fed in the framework development stage.

1.6.5 Research Ethics

The research instruments and the methodology were approved by the Natural and Applied Sciences Research Ethics Committee (NASREC) before collecting the data. Additionally, ethics were upheld throughout the research for instance the confidentiality of respondents. During the overt observation, when photographs were taken, the faces of the worker were avoided.

1.6.6 Bias

Biasness in the research was mitigated by the use of mixed methods of quantitative and qualitative. Quantitative methods involved experimental and questionnaire survey while observation was under qualitative methods.

1.6.7 Validity

Validity deals with the accuracy of a measure of the research instrument. The dust sampling instruments which included a pump, 25mm PVC filters, cassettes and cyclones were calibrated before use. Calibration validates an equipment. The sampling and analysis methods of MDHS14/4 and MDHS101/2 are international standardised methods (HSE, 2014; HSE, 2005). The questionnaire survey was pretested using a pilot on 10 skilled workers for content validity and what was not clear was simplified and corrected accordingly.

1.6.8 Reliability

Reliability deals with consistency of the measure. The measure of internal consistency which measure reliability is established by calculating Cronbach's alpha coefficient. Cronbach's alpha coefficient ranges from 0 to 1 and the closer the coefficient is to 1, the higher the reliability. Experimental results were reliable as the Cronbach's alpha was 0.876. Likewise, phase two questionnaire results were reliable as Cronbach's alpha was 0.702. Phase one questionnaire responses were similar to the results which were obtained from the overt observations. In addition, the questions in the phase one questionnaire were similar to what was in the observation schedule. Therefore, phase one questionnaire results were reliable according to inter – item reliability.

1.7 Application of the Research/Significance

The final outcome of this research was the development of an integrated preventive framework to help mitigate silica dust and chemical irritant exposures in the construction industry in Zambia. The framework would be used by construction stakeholders to put in place correct measures to reduce exposure to silica dust and chemical irritants thereby protecting construction specialised workers and the prevent the effects of such hazards on the projects. The resulting framework would also generally improve safety and health culture in the construction industry. Moreover, the research would aid the Zambian Government through its agencies in raising awareness and mitigating silica dust and chemical irritant exposures through policy formulation. The following were the relevant expected results from the research.

- i) Establishing the concentration of silica dust levels, the construction specialised personnel were exposed to in the construction industry in Zambia in relation to OSHA PEL of $0.05\text{mg}/\text{m}^3$.
- ii) Assessing the dust levels in relation to the prevalence of symptoms of respirable diseases.
- iii) Determining the levels and period of exposure to chemical irritants in relation to prevalence of symptoms of skin disease for construction specialised personnel in Zambia.
- iv) Identifying current existing controls for silica dust and chemical irritants and how they relate to prevalence of symptoms of respirable and skin diseases.

1.8 Limitation of the Research

The research is limited to silica dust, and in terms of chemical irritants it is limited to cement, paint, concrete, tile fix and resin epoxy. Moreover, it is limited to hazards and symptoms of respiratory and skin diseases that have been mentioned in the research such as silicosis and dermatitis respectively. This is a cross sectional research, therefore does not include any medical check-up or observing the disease progression in the workers. Medical examinations for both lung function and patch tests were included in the resulting preventive framework. The research is also limited to a road and building projects; however, it could be generalised to all construction sections that utilise activities that are performed by the sampled specialised workers as they are similar in the construction industry. Moreover, the

use of two cases studies: a road and a building project was to ensure a good representation of the construction industry. The specialised workers in this research are bricklayers, tilers, carpenters, batchers, demolition workers, handymen and road construction workers. Finally, the research is limited to the exposure levels of silica dust and chemical irritants and the preventive measure that exist in the construction industry.

The silica dust samples were supposed to be 30 in total; 15 on the building project and 15 on the road project. The 15 samples on the road project were not possible to collect as it was during the rainy season and there was no dust generated. Most road work activities were suspended because of flooding. Silica dust measurements were limited to 30 samples because the silica dust sampling equipment and media were hired from National Institute for Occupational Health (NIOH) in South Africa. Silica dust analysis was also done by NIOH South Africa. This was because the OHSI in Zambia had no facilities to sample and analyse silica dust at the time of the study. The actual silica dust samples collected were 15 from the building project. The sample size for the first phase questionnaires was limited to 100 as there was a reduction of workers as one of the requirements from Ministry of Health Covid-19 Prevention Guidelines. Moreover, most workers wore face masks as it was mandatory because of Covid-19. This would have affected the results as during observations only one worker wore a dust masks all workers were in face masks.

1.9 Organisation of the Thesis

The thesis is organised in seven chapters.

Chapter one gives the background, research problem, purpose of the research, aim and objectives, research questions, summary of the methodology and significance of the research.

Chapter two presents the review of relevant literature on the research topic. The importance of silica dust and chemical irritants hazards, silica dust exposure levels for construction skilled personnel and symptoms of respiratory diseases are discussed. In addition to the silica concentration, the importance of exposure levels being below OSHA PEL is explained. Levels and period of exposure to chemical irritants in relation to the occurrence of symptoms of skin diseases are also

deliberated. The importance of the hierarchy of controls in mitigating silica dust and chemical irritants is emphasised and discussed in chapter two. Moreover, the research theoretical framework, conceptual framework and hypotheses are presented.

Chapter three provides the research methodology which includes the research philosophical point of view, design, methods of data collection and analysis and research ethics.

Chapter four presents the research findings and testing the research hypotheses.

Chapter five discussed the research findings.

Chapter six provides the preventive framework development and validation process.

Chapter seven concludes the research findings by evaluating the research objectives and gives recommendations and implication of the research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

According to Saunders et al. (2000), literature review forms the framework on which research is based as it helps to develop a good understanding and insight into relevant previous research and emerging trends. International and local legal frameworks on occupational safety and health were reviewed as a guide for the research. Studies conducted by other scholars on silica dust and chemical irritants in the construction industry were reviewed in terms of levels of silica dust and chemical irritants, prevalence of symptoms of respiratory and skin diseases and controls of silica dust and chemical irritants in the construction industry. Moreover, the preventive frameworks that have been developed by other researchers were also reviewed to guide the development of an integrated preventive framework for this research.

‘Exposure’ is defined as the concentration of airborne occupational crystalline silica dust measured in the workers’ personal breathing environment (Yassin et al., 2005). In the case of chemical irritants, exposure is when the skin of the workers comes in to contact with the chemical irritants when working with different construction materials that contain such chemicals. Respirable Crystalline Silica dust in this study has the same meaning as silica dust. Keywords such as ‘silica dust exposure in construction’, ‘chemical irritants in construction’, ‘symptoms respirable diseases due to silica dust exposure’, ‘symptoms skin diseases due to exposure to chemical irritants’, ‘silica dust controls in construction’ were used in the google scholar, Research gate, Scopus, PDF Drive, HSE, OSHA and other databases for published, peer reviewed articles, theses, books, reports, Acts and documents.

2.2 Research Legal Frameworks on Occupational Health and Safety

The legal frameworks are a set of guidelines that are enforceable and dictate how governments, institutions or companies and people in terms of their responsibilities and rights are governed (Natural Resource Governance Institute, 2015). In this research, some of the international and local frameworks on occupational health, safety, environment and construction were used.

2.2.1 International Legal Frameworks

The international frameworks that were considered in this research were; Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187), Occupational Safety and Health Administration Permissible Exposure Limits, American Conference of Governmental Industrial Hygienists Threshold Limits Values and National Institute for Occupational Safety and Health Recommended Exposure Limits.

a) Promotional Framework for Occupational Safety and Health Convention, 2006

The Promotional Framework for Occupational Safety and Health Convention, 2006 is an International Labour Organization convention that was adopted on 31 May 2006. This convention was adopted to support the Occupational Safety and Health Convention, 1981 (Number 155), to reduce occupational deaths, injuries and diseases and their effects on production and most importantly safeguarding the life and health of workers in all sectors of the economy (Promotional Framework for Occupational Safety and Health Convention, 2006). It came into enforcement on 20 February 2009. All member countries that ratified this convention are expected to prevent occupational deaths, diseases and injuries through the national policies. Zambia is among the member countries that ratified the Promotional Framework for Occupational Safety and Health Convention, 2006. Therefore, the convention is important in this research as it is the basis of reduction of occupational hazards such as silica dust and chemical irritants in construction.

b) Occupational Safety and Health Administration Permissible Exposure Limits

Occupational Safety and Health Administration Permissible Exposure Limits (OSHA PELs) are mandatory, exposure legal limits that are enforceable under Occupational Safety and Health Act of the United States of America (USA). The OSHA PEL for respirable crystalline silica in construction industry is $0.05\text{mg}/\text{m}^3$ in 8-hour Total Weighted Average (TWA). The PEL for respirable dust is $5\text{mg}/\text{m}^3$ and total dust is $15\text{mg}/\text{m}^3$ respectively.

c) American Conference of Governmental Industrial Hygienists (ACGIH)

The American Conference of Governmental Industrial Hygienist (ACGIH) is a charitable scientific organization that advances occupational and environmental health through the recommendations for safe levels of substances. The recommendations are derived from scientific and toxicological information. Therefore, the ACGIH safe levels are health-based guidelines and are called Threshold Limit Values (TLVs). The ACGIH TLV for respirable dust should be below $3\text{mg}/\text{m}^3$ and inhalable dust below $10\text{mg}/\text{m}^3$ over 8-hour TWA respectively (NIOSH, 2018).

d) National Institute for Occupational Safety and Health

The National Institute for Occupational Safety and Health NIOSH is a research agency under Centers for Diseases Control and Prevention (CDC) which is mandated to safeguard the safety and health of workers in USA. The NIOSH has Recommended Exposure Limits (RELs) TWA concentrations for dust that should not be exceeded over an 8 or 10-hour work shift. The NIOSH REL for respirable crystalline silica is $0.05\text{mg}/\text{m}^3$.

e) Health and Safety Executive

The Health and Safety Executive (HSE) is a safety and health regulator in Great Britain whose mandate is to prevent workplace accidents and ill-health. Workplace Exposure Limits (WELs) are legal limits which are not supposed to be exceeded. The crystalline silica dust WEL for HSE is $0.1\text{mg}/\text{m}^3$, respirable dust is $4\text{mg}/\text{m}^3$ and total dust is $10\text{mg}/\text{m}^3$ over 8-hour TWA (HSE, 2020). Despite the WELs being legally binding, they are not supposed to be exceeded.

Comparing the exposure limits for OSHA, ACGIH, NIOSH and HSE, the lowest crystalline exposure limit is OSHA PEL which is $0.05\text{mg}/\text{m}^3$ over 8-hour TWA. Any crystalline silica dust exposure levels above $0.05\text{mg}/\text{m}^3$ are considered a risk to the workers as these levels may have hostile health effects (OSHA, 2017).

2.2.2 Zambian Legal Frameworks

The legal frameworks in Zambia that were used for this research were: Occupational Health and Safety Act (OHS, Act of 2010); Factories Act; Environmental Protection and Pollution Control Act (ZEMA); Public Health Act; National Council for

Construction (NCC) Act; Workers compensation Act; and Mines and Minerals Development Act.

a) Occupation Health and Safety Act

The Occupational Health and Safety Act was enacted on 19 November, 2010. It was passed to establish Occupational Health and Safety Institute for the purposes of safeguarding workers' health, safety and warfare in all industries. The OHS Act, 2010 provides for the responsibilities of all industry stakeholders in terms of health, safety and workers warfare at work places (OHS Act, 2010). It was enacted in accordance to the International Labour Organization's Promotional Framework for Occupational Safety and Health Convention, 2006 which Zambia ratified as a member state.

In this study, the OHS Act was used as the main legal framework because it was the legal framework for all industries including the construction industry. Moreover, it incorporates all the other legal frameworks concerning occupational health, safety, environment and workers' warfare in the construction industry such as the Factories Act, Environmental Protection and Pollution Control Act, Public Health Act, National Council for Construction Act, Workers Compensation Act and Mines and Minerals Development Act.

b) Factories Act

The Factories Act Chapter 441 was first enacted in 1966 and was latest amended in 1994. It was enacted to regulate factories in terms of safety, health and warfare of employees in a factory. For the purposes of this research the section of interest in the Factories Act is Part IX which is on Warfare and General Provisions and Part X on Health, Safety and Welfare: Special Provisions and Regulations. These sections of the Factories Act give the requirements in terms of provision of clean drinking water, wash and change rooms, First Aid, and removal of dust and controls to prevent inhalation through other measure including the use of exhaust appliances (Factories Act, 1994).

c) Environmental Management Act

The Environmental Management Act was enacted in 2011 to protect, conserve the environment and the sustainable use of natural resources. In addition, it was enacted for prevention and pollution control (Environmental Management Act, 2011). This research focuses on Part IV of the Environmental Management Act which deals with Environmental Protection and Pollution Control especially on air pollution.

d) Workers Compensation Act

The Workers Compensation Act was amended in 1994 to establish Workers Compensation Fund for the purposes of compensating workers who die, get injured or develop diseases as the result of their work. This research's focus is on Part IX which is on diseases. Part IX deals with the compensation as a result of occupational diseases such as pneumoconiosis which is as a result of inhaling dust (Workers Compensation Act, 1994).

e) Mines and Minerals Development Act

The Mines and Minerals Act was enacted to revise the law concerning to the exploration, mining and processing of minerals and provision of health, safety and environment protection during the operations. It replaced the Mines and Minerals Development Act, 2008 and led to the establishment of mining appeals tribunal. The Mines and Minerals Act is important in this research because of Part VI which relates to health, safety and environment protection.

f) National Council for Construction (NCC) Act

The National Council for Construction Act No. 10 of 2020 was enacted on 19 November 2020 for the purposes of developing, regulating the construction industry for economic growth, sustainable employment, enhancement of technical compliance and developing capacity for contractors. Also to collaborate with professional bodies involved in construction activities and continuation of the National Construction School (NCC Act, 2020). The importance of the NCC Act in this research was its legality of governing all activities in the construction industry from registration and regulation of contractors and suppliers to inspections during the construction stage of any infrastructure.

It is important to note that despite the Zambian legal limit for dust ($1.7\text{mg}/\text{m}^3$) being less than OSHA PEL for respirable dust ($5\text{mg}/\text{m}^3$), Zambia has no legal limit for crystalline silica dust which is the most harmful part of dust. It is crystalline silica dust that has more adverse effects on the workers when it is inhaled as it causes symptoms of respiratory diseases such as silicosis and lung cancer. Among the respirable diseases caused by crystalline silica dust hazard, silicosis is lethal and has no known cure (Li et al., 2019).

The importance of the reviewed international and local legal frameworks was to highlight the basis of the research in terms of existing guidelines in terms of occupational health and safety. However, the framework to be developed in this research will incorporate Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187) and the OSHA PELs as international frameworks and the OHS, Act of 2010, Factories Act; the ZEMA, Act; Public Health Act; the NCC Act; Workers compensation Act; and Mines and Minerals Development Act as local frameworks. These frameworks relate to the silica dust and chemical irritant hazards.

2.3 Dust and Silica Dust Hazard

Dust is generated in many industries including the construction sector through crushing, breaking, cutting, crushing drilling, stone breaking (Normohammadi et al., 2016). Examples of construction materials that produce dust are cement, concrete, lime, sands, bricks and stones (Wu et al., 2016). Dust is a combination of different types of dusts namely total dust, respirable and silica dust. Quartz is the most common form of crystalline silica and it is the most abundant component in the earth (Peters et al., 2011). According to HSE, (2012), silica dust is more hazardous when inhaled as it causes respirable diseases such as chronic obstructive pulmonary disease, renal disease, tuberculosis, lung cancer and silicosis. Silicosis is the scarring of lungs and is progressive in the advanced stages even with stoppage of exposure. Silicosis is irreversible, fatal and has no known cure (Li et al., 2019). In the United Kingdom's construction industry past exposure to asbestos and silica accounted for 40% of occupation cancer (HSE, 2014).

2.3.1 Silica Dust Exposure Levels in Construction

Silica is found in construction materials such as sand, stone, brick, mortar and concrete (OSHA, 2017). Therefore, when working with these materials, silica dust is produced. Some of the common construction activities that produce silica dust are surface grinding and finishing, tuck-point grinding (mortar removal), rock and surfacing grinding, sanding of drywalls, tile cutting, brick and concrete block cutting and abrasive blasting (HSE, 2012). Since silica dust is produced from the construction staple materials, it is one of the important hazards in the construction industry (Kirkeskov et al., 2016; Wiebert et al., 2012; Flanagan et al., 2003).

Several countries have recorded high silica exposures that pose a high risk of respiratory diseases to construction workers. Thus, there is a concern for the high silica dust exposure levels in construction. According to Moser (1992), in Switzerland, 80% of the measurements of exposure levels for demolition and reconstruction were above $0.15\text{mg}/\text{m}^3$ and beyond the Threshold Limit Values (TLV). According to Riala (1988), Finland recorded silica exposure levels of $0.53\text{mg}/\text{m}^3$ during dry season. Similarly, Lumens and Spee, (2001), suggested that the Geometric Mean (GM) for silica exposure ($0.5\text{mg}/\text{m}^3$) was above $0.075\text{ mg}/\text{m}^3$ in Netherland's construction industry.

There are some factors that contribute to high silica exposure levels in construction. Some of the factors are; enclosed space or no natural ventilation for some works, (Li et al., 2019), dusty working methods, less use of Local Exhaust Ventilation (LEV), improper use of Respiratory Protective Equipment (RPE) and the use of high silica content materials (Lumens and Spee, 2001). Several studies have recorded different silica content. Li et al., (2019) reported 15%, Lumen and Spee (2001) found over 40% and Flanagan et al (2003)'s study recorded the range between 2.2 to 21%. The higher the silica content in construction materials the more they produce RCS dust when they are being worked on and the higher the likelihood of high exposure levels. Therefore, there is need for possible reduction of silica content in construction materials as one of the ways to reduce exposure levels (Thorpe et al., 1999). Lumens and Spee, (2001) indicated that dust exposure on construction site is unavoidable in the sense that important construction activities and staple materials generate dust.

However, many people are not aware of dust as a potential hazard especially RCS (Lumens and Spee, 2001).

Exposure to respirable dust in construction depends on the tasks and profession (Kirkeskov et al., 2016). This means that silica dust exposure levels differ from profession to profession and task to task despite working on the same construction sites. Several studies have been conducted to measure the levels of exposure on different construction activities and professions. Flanagan et al. (2003), found that surface grinding had more exposure levels of silica dust compared to sacking and patching concrete, concrete cutting, tuck-point grinding, demolition with handheld tools and concrete floor sanding. The average silica concentration in the tasks was $0.11\text{mg}/\text{m}^3$ which exceeded the Threshold Limit Value (TLV) of $0.05\text{mg}/\text{m}^3$ (Flanagan et al., 2003). Similarly, Li et al., (2019) found that ten percent of the samples exceed $0.05\text{mg}/\text{m}^3$ and they were activities such as cement mixing, concrete breaking and manual demolition.

On the profession, there are several studies with findings that demolition workers are exposed to higher levels of silica dust. Demolition workers were exposed to higher level of silica dust (GM of $1.1\text{mg}/\text{m}^3$) beyond the Dutch exposure limit of $0.075\text{mg}/\text{m}^3$ (Lumens and Spee, 2001). Normahammadi et al. (2016), also found that demolition workers were found to be exposed to silica dust levels more than Occupational Exposure Limit (OEL). The Geometric Mean (GM) was $0.132\text{mg}/\text{m}^3$ and the Arithmetic Mean (AM) was $0.190\text{mg}/\text{m}^3$ and both the GM and the AM were above the old and new OEL of $0.050\text{mg}/\text{m}^3$ and $0.025\text{mg}/\text{m}^3$ respectively. Similarly, in the study by Kirkeskov et al. (2016), the silica dust concentration for demolition workers for the calculated 8-h-TWA was $0.08\text{mg}/\text{m}^3$ which was more than carpenters. Despite the concentration of $0.08\text{mg}/\text{m}^3$ being lower than the OEL of $0.1\text{mg}/\text{m}^3$, 45% of individual measurements for demolition workers calculated at 8-h-TWA exceeded the OEL of $0.1\text{mg}/\text{m}^3$ for RCS in Denmark. However, Flanagan et al. (2003) found that abrasive blasters, surface and tuck-point grinders, jackhammers and rock drills had high silica dust exposures. Moreover, Flanagan et al, (2003) established that construction masons and labourers were frequently overexposed ($0.11\text{mg}/\text{m}^3$ compared to the limit of $0.05\text{mg}/\text{m}^3$) to silica dust even though they prefer working without respirators. On the other hand, Rappaport et al,

(2003) reported that painters experienced the highest exposure to silica dust of 1.28 mg/m³ which was beyond the OEL of 0.05mg/m³.

Kirkeskov et al. (2016) found that the respirable dust GM for demolition workers was higher (1.06mg/m³) compared to GM for carpenters (0.27mg/m³). However, both concentrations for demolition workers and carpenters were below the OEL of 5mg/m³. In addition, one of the individual measurement (5.02 mg/m³) exceeded the OEL of 5 mg/m³ for RD. Lumen and Spee (2001) reported similar findings of demolition workers being exposed to higher levels of RD. However, the levels in Lumen and Spee (2001) study were above the limit of 5mg/m³ for the GM of all samples was 5.2mg/m³ and the GM for demolition workers was 10.8mg/m³. The difference in levels of RD exposures in the two studies would have been that Kirkeskov et al. (2016) sampled demolition workers and carpenters while Lumen and Spee (2001) sample recess millers, inner wall constructors and demolition workers. Another difference was that Lumen and Spee (2001) did not use the full day shift while Kirkeskov et al. (2016) used the full day shift. In Zambia, Nsunge (2019) reported RD concentration of 1.768mg/m³ among road construction workers which was slightly above the legal limit in Zambia (1.74mg/m³).

2.3.2 Prevalence of Symptoms of Respirable Disease in Construction

In the study by Nirmala and Prasad (2019), the prevalence of respiratory problems was high among construction workers. The prevalence was 26% and may have been as a result of increased dust, paint and allergens. The common complaints in terms of symptoms were coughing and difficulties in breathing. This is similar to Saji et al. (2018) who established that the common symptoms of respirable diseases were persistent cough, breathlessness, wheezing, irritation in the throat and sneezing among cement workers. Adsul et al. (2011) found that the prevalence of respirable infections was 12.6% among the migrant construction workers in India. In the road construction in Zambia, Nsunge (2019) found that workers experienced respiratory diseases. The prevalence by respiratory symptoms were 59% of the workers experienced nose irritation, 45% wheezing, 39% shortness of breath and 29% phlegm.

Previous studies have shown that there is a relationship between the dust exposure levels and prevalence of symptoms of respiratory diseases (Nsunge, 2019; Ahmed and Abdullah, 2012). In these two studies, modified American Thoracic Respiratory Questionnaire (ATRQ) and Medical Research Council Questionnaire (MRCQ) were used respectively.

2.4 Chemical Irritants in Construction

Chemical irritants are materials that cause reversible irritation to the skin, eyes and airways after a single exposure (OSHWIKI, 2017). According to ENVIS-NIOH (2010), examples of chemical irritants are; cement, metal and resins and may cause skin allergies if sufficient exposure takes place. These account for 75 per cent of the occupational dermatitis. Lushniak (2004) defines Contact Dermatitis as an inflammatory skin condition caused by skin contact with one or more external agents as a result of exposure to that agent. Some of the symptoms of contact dermatitis are itching, redness, thickened, fissured and scaly skin and appearance of lesions (ENVIS-NIOH, 2010; Bourke et al., 2009). There are two major types of contact dermatitis namely; irritant contact dermatitis and allergic contact dermatitis.

The strong irritants can induce an acute reaction within minutes of exposure. However, clinical signs usually appear after repeated exposures (Cashman et al., 2012). Contact dermatitis accounts for 60% of dermatoses and generally accounts for 40-70% of occupational illness. Contact dermatitis can occur anywhere depending on the exposed area of the body although the most affected are the hands, fingers, wrists and forearms. If the exposure continues over an extended period, dermatitis becomes chronic (ENVIS-NIOH, 2010).

Hand eczema, which is part of the symptoms of dermatitis, decreases quality of life by physical and psychological burden, time consuming treatment and may lead to change in occupation (Skoet et al., 2010; Verhoeven et al., 2007). Hand contact dermatitis is susceptible to recurrence and complete recovery is very difficult and may compromise the efficiency of workers (Bhattarai et al., 2015). Other effects of skin diseases are sick leave of at least seven days on one occasion during life and job change (Meding and Swanbeck, 1990). Moreover, there are cost implications like insurance claims and medical treatment (Skoet et al., 2010).

2.4.1 Levels and Period of Exposure to Chemical Irritants

(a) Levels of Exposure to Chemical Irritants

Several studies have revealed that the levels and period of exposure to chemical irritants are important to the development of skin diseases. According to Mashqoor et al. (2017), 78% of the workers did not have any Personal Protective Equipment (PPE). Similarly, in the study by Bedoya-Marrugo et al. (2017), 70% of respondents did not use PPE. Moreover, Shah and Tiwari (2010) found that 50% of the workers did not use PPE. This meant that the workers without PPE experienced high exposure levels to chemical irritants and were likely to develop symptoms of skin diseases. This would have been the reason for high rate of skin diseases in the construction industry.

(b) Period of Exposure to Chemical Irritants

Period of exposure to chemical irritants have also been associated to occurrence of symptoms of skin diseases. Shah and Tiwari (2010) found that there was an association between increased duration (8-10 hours) of exposure and skin conditions. The skin symptoms were work related and were aggravated by work. In the study by Bedoya-Marrugo et al. (2017), it was found that the period of exposure to cement was directly proportional to likelihood of developing dermatitis. Esmail and Sakwari (2021) also found that exposure in terms of work duration was associated with the occurrence of skin diseases. Prolonged duration of exposure was associated with more morbid skin conditions (Moshqoor et al., 2017).

2.4.2 Prevalence of Symptoms of Skin Disease in Construction

Irritant contact dermatitis is common in construction and is caused by a chemical or physical agent (Timmerman, 2017). In the study by Shah and Tiwari (2010), 47.8% of the construction workers were found with skin symptoms which included friction callosities, contact dermatitis, fissured and scaly skin. Most of the skin symptoms are associated to dermatitis. Construction workers are at risk of irritant contact dermatitis which is caused by cement (Bock et al., 2003). Cement is widely used in construction despite it being a hazard (Spoo and Elsner, 2001). Contact with wet cement may cause pain and burning sensation (Behrangi et al., 2014). Wet Portland cement causes caustic burns known as cement burns that may result in blisters and hardened skin. Unfortunately, in severe cases may cause disfiguring if it extends to

the bone (ENVIS-NIOH, 2010). Workers who come into contact with cement frequently have been associated with irritant contact dermatitis (Iraji et al., 2006).

Bock et al, (2003), found that epoxy resin is the second common occupational relevant irritants to cement. Other irritants in construction are chromate, solvents, oils and greases, asphalt, acids and alkalis and abrasive materials especially in wet works (Ronmark et al., 2012). Workers are also exposed to latex and preservatives (Iraji et al., 2006). Rubber gloves and boots can also cause allergy (ENVIS-NIOH, 2010).

Construction is of the most affected by the skin diseases compared to other industries (Lim and Goon, 2007). Cement contains potassium dichromate which causes skin diseases (Sharma et al., 2017). The prevalence of skin diseases in Indian in a study by Mashqoor et al. (2017) was at 60% of the construction workers. In the United States of America, the prevalence among Latino migrant construction workers was 23% (Quardt et al., 2014). Timmerman (2017), found that the prevalence in the Netherland construction industry was 25.4%. According to Esmail and Sakwari (2021), prevalence was 54% among building workers in Tanzania. The prevalence of skin diseases in the construction industry in Zambia was 14% (Tente, 2016). The most common symptoms of skin diseases are itching, redness, thickened, fissured and scaly skin and lesions (Bourke et al., 2009). Skin diseases are costly to society (Skoet et al., 2004) and may result in emotional and physical morbidity (Handa et al., 2012). The effects of skin diseases are not only detrimental to the health of the workers but also affect construction projects as the results of loss of man-hours. The workers become ineffective on the project, thereby failing to meet construction schedules.

Certain occupations such as bricklayers, plasterers and cement workers are more likely to suffer from dermatitis as they are often exposed to dust and substances with irritant properties such as wet cement, epoxy resins, solvents and abrasive materials (Timmerman, 2017). Dust exposure was found to be the most important work-related determinant for hand eczema symptoms among construction workers (Timmerman, 2017). This entails that construction workers are at risk of developing occupational contact dermatitis. Dust may contain eczema causing components, like

gypsum drywall dust that dehydrates the skin (Timmerman, 2017). Another occupation that is at risk of dermatitis are painters even though their use of gloves is low (Timmerman, 2017).

2.5 Silica Dust and Chemical Irritants Controls in Construction

The controls of respirable crystalline silica dust and chemical irritants fall within the hierarchy of controls. The hierarchy of controls has five controls: elimination, substitution, engineering control, administrative control and the use of personal protective equipment (ENVIS-NIOH, 2010).

2.5.1 Elimination method

Elimination method involves the physical removal of a hazard and is the most effective control. However, elimination method is almost not practical in construction especially with the use of crystalline silica materials that are extensively used like cement and sand (Thorpe et al., 1999). In the case of chemical irritants, elimination entails preventing the skin from being in contact with chemicals.

2.5.2 Substitution method

Substitution method is replacing the more hazardous materials or activities with lesser hazardous ones (Radnoff and Kutz, 2014). Mwanaumo et al. (2014) found that there is a relationship between hazard recognition and specification of less harmful materials. In addition, part of preventive strategies, substitution of materials with high quartz content lowers quartz exposure concentrations (Boudigaard et al., 2022). For example, in the study by Kirkeskov et al. (2016), substituting manual demolition with mechanical demolition would be recommended. This is because manual demolition had higher total dust exposure levels of 177mg/m³ compared to mechanical demolition recorded exposure levels of 4.4mg/m³ (Kirkeskov et al., 2016). Nevertheless, in some cases substitution method does not make much difference like in the case of Radnoff and Kutz (2014), the use of silica substitute did not have a large effect on the exposure levels. An example of a meaningful substitution method is the replacement of onsite mixing of concrete with the use ready mix concrete (Wu et al., 2016). Another example of substitution method is in the study by Bock et al (2003) where high chromate cement was identified as a hazard and was later replaced by chromate-reduced cement which was less harmful.

2.5.3 Engineering control

The Engineering control is the way of removing the hazard at the source before it comes into contact with the worker. One example of engineering control is the use of face shields to protect the face from exposure to chemicals. There are several engineering respirable crystalline silica dust control methods that are used in the construction industry. Some of the engineering controls employ the use of area fans, ducted fan exhaust, sweeping compound (dyed saw dust, sand and oil) and water application to cutting materials (Flanagan et al., 2003).

- i) Area fans are positioned to carry dust-laden air away from the area.
- ii) Ducted exhaust fans take dust outside the building.
- iii) Sweeping compound such as dyed sawdust, sand and oil are broadcasted over the floor before sweeping.
- iv) Applying water to a saw blade when cutting materials that contain crystalline silica such as stone substantially reduces the amount of dust created during the operation. This is similar to findings of Boudigaard et al. (2022) that the use of water on the powered tools reduces silica exposures.

The General Ventilation (GV), Local Exhaust Ventilation (LEV) and wet dust suppression are also used to control respirable crystalline silica exposure (Li et al., 2019; Lumens and Spee, 2001; Thorpe et al., 1999). Local exhaust ventilation involves the capture of air contaminants at a source. A local exhaust ventilation system consists of a hood or enclosure to capture a contaminant, an air pollution control device to clean the air, and an air mover to provide air flow through the system (Raynor and Peters, 2016). These systems range from small portable units, such as a High-Efficiency Particulate Arrestance (HEPA)-vacuum system as shown in Figure 2.1a, to extensive, permanent installations typical of large industrial facilities in Figure 2.1b (ibid). The air containing dust is then filtered before it is released to the air (Hasan et al., 2012).

The wet dust suppression is done by applying water to the rotating cutting disc of the powered hand tools to reduce dust emission (Thorpe et al., 1999). Flanagan et al. (2006), in their study established that engineering controls reduced silica dust exposure. Unfortunately, the engineering controls, were infrequent and so did not control exposure below the PEL of 0.05 mg/m^3 which was used for their study.

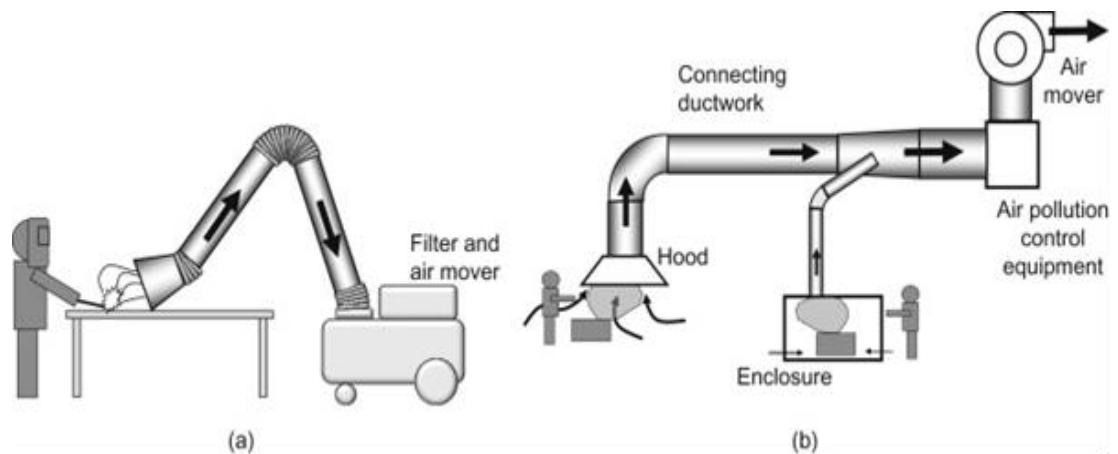


Figure 2.1: High-Efficiency Particulate Arrestance (HEPA)-vacuum system (a) and Permanent Installations Typical of Large Industrial Facilities (b). (Source Raynor and Peters, 2016).

2.5.4 Administrative Controls

Administrative controls deal with the change of behaviour of workers in terms of training and awareness on how to lessen the risk of a hazard on an individual (NIOSH, 2009). For example, offering training in the proper use of tools fitted with controls for crystalline silica exposure to the workers has been recommended (HSE, 2012). Ensuring that workers rotate in terms of hours of work shifts when working on a high silica dust producing activity to keep exposure under PEL, is one of the examples of administrative controls of exposures (Tente et al., 2022). Administrative controls are mostly recommended when elimination, substitution and engineering controls have failed to completely control the hazard (NIOSH, 2009). Administrative control also includes toolbox talks and risk assessment trainings conducted every day before any task in undertaken.

Pre-employment training in safety and health would help in prevention of skin diseases (Coenraads et al., 1984). This would come in terms of providing training program to workers on handling hazards and how to protect themselves. In addition, provision of improved work place health education, adequate health services and improving professional skills can prevent skin diseases (Mashqoor et al., 2017). Awareness of risk of contact dermatitis in the construction industry should increase (Timmerman, 2017). Shah and Tiwari (2010) suggested that to prevent skin diseases, employers should provide social security services, offer health education and

encourage good personal hygiene to the construction workers. Timmerman (2017) was for the idea that construction workers should be made aware of the risks and prevention of skin problems during their vocational training. Moreover, change of legislation can also be helpful to reduce exposure to chemical irritants. The legislation that was passed in European Union countries of decreasing amount of hexavalent chromium in cement from 43.1 to 29.0% led to a great decline in chromate sensitization among construction workers (Timmerman, 2017). Another example of administrative control is the encouraging workers to wash hands thoroughly after work (Timmerman, 2017) and apply petroleum jelly to moisturize, heal and restore the skin wounds (Lalonde et al., 2019).

2.5.5 Personal protective equipment (PPE)

The full PPE consists of a work suite or overall, safety shoes or boots, reflector vest (if the work suite or overalls have no reflectors), hardhat, safety goggles, respirators or dust masks, gloves and earplugs. The PPE is worn to protect the workers from exposure to dust, chemicals, sound and other materials or hazards that can harm them. This is supposed to be the last control when all the other controls have been put in place.

Since the use of engineering controls such as wet dust suppression and LEV do not completely eliminate respirable crystalline silica dust below PEL, Respiratory Protective Equipment (RPE) is required (HSE, 2012). The RPE is the type of PPE which protects from inhaling hazardous vapour, gases or fine solid or liquid in a gas form (Howie, 2005). According to Ahmed and Abdullah (2012), the most common control used for silica dust in the construction industry was RPE. Despite this fact, respiratory protection is usually inadequate for the exposures that are encountered in construction (Flanagan et al., 2003). In addition, when respirators do not fit well and is wrongly selected, it compromises protection and gives a false sense of protection to the one wearing it (HSE, 2010). Therefore, proper selection of the RPE should be done and they have to be stored properly (Radnoff and Kutz, 2014). Unfortunately, Kirkeskov et al, (2016) found that only few workers used personal respiratory protection and only while performing the dustiest work. This is the more reason why engineering controls should be encouraged. Moreover, respirators only protect the user not the nearby workers. Even though quality and efficient respirators

are more expensive and require maintenance, they have to be provided to effectively control dust exposure levels of workers (Flanagan et al., 2003).

It is common in construction, for workers not to wear PPE for various reasons. According to Mashqoor et al. (2017), 78% of the workers did not have any protective measures and that would have been the reason for high rate of dermatitis in the construction industry. Similarly, in the study by Bedoya-Marrugo et al, (2017), 70% of respondents did not use PPE, this means more workers were exposed to chemicals and were likely to develop symptoms of skin diseases. Moreover, Shah and Tiwari (2010) found that 50% of the workers did not use PPE. However, of those who used PPE, 45.2% still developed symptoms of skin diseases (Shah and Tiwari, 2010). This would have been that the PPE was unsuitable or was used wrongly.

The compilation of the results from some studies on reduction by type of controls are presented in Table 2.1. No single control was able to reduce exposure below PEL. Water control which has a reduction of above 90%, was more effective compared to LEV and the use of silica substitute materials. However, there were few concerns with water in terms of slip hazards and decolouring during roofing when cutting tiles with the saw (Carlo et al., 2010). The effectiveness of water to reduce silica dust exposure on the on-tools depended on the water volume, flowrate and the blade size. Nevertheless, in some studies which were done on the controls of respirable crystalline silica exposure, there was no statistical significance effect in control efficiency for factors such as water volume, flow rate and blade size (HSE, 2012).

The other control which reduced exposure by 99% was LEV on-tool. The advantage of LEV was that it reduced exposure to nearby workers and minimised the clean-up due to dust exposure. The problem with LEV on-tool was that it added more weight to the equipment or tool. The use of silica substitute materials reduced 60% of exposure. This meant that the use of silica substitute materials should be incorporated in construction to help reduce exposure levels. The combination of LEV and water showed significant reduction which was below the PEL of $0.075\text{mg}/\text{m}^3$.

Table 2.1: Silica Exposure Reduction by Some Authors

Item	Control Type	No Control (mg/m ³)	Control (mg/m ³)	Reduction %	PEL (mg/m ³)	Source
1	Pressure Tank	21.2	1.3	95	0.4	Thorpe et al., (1999)
	Mains Water	14.4	0.6	93		
	LEV	8	0.7	91		
2	LEV	1.0	0.3	70	0.075	Lumens and Spee (2001)
3	LEV on-tool and Box Fan	4.87	1.42	71	0.05	Flanagan et al. (2003)
4	LEV and Water	14.3	Below PEL	99	0.075	Tjoenij, et al.(2003)
5	LEV	4.5	0.14	86	0.05	Croteau et al. (2004)
6	LEV on-tool	61.7	0.90	99	0.025	Akbar-khanzadeh, et al. (2007)
	Wet grinding	61.7	0.15	98		
7	LEV	1.4	0.13	91	0.075	Carlo, et al. (2010)
	Water suppression	3	0.03	99	0.075	
8	Silica substitute	0.074	0.049	66	0.025	Radnoff and Kutz (2014)

This clearly shows that the combination of all controls which are LEV, water, the use of silica substitute materials, training and the proper use of quality RPE would reduce exposure to safeguard the workers' health which is paramount. More research was recommended especially in developing countries to assess silica exposure levels in construction and find preventive measures that would help reduce the high levels of silica dust exposure.

2.5 Frameworks

The framework that were accessed in this study were framework for program evaluation, spectrum of prevention framework and strategic prevention framework.

2.5.1 Framework for Program Evaluation

The framework for program evaluation is a practical, nonprescriptive tool, designed to summarize and organize essential elements of program evaluation (Centers for

Disease Control and Prevention, 1999). This framework consists of six main interdependent steps which are conducted based of four standards. The six steps are engage stakeholders, describe the program, focus the evaluation design, gather credible evidence, justify conclusion and ensure use and share lesson learned.

i) Engage stakeholders

This is the first step in the evaluation cycle where all the stakeholders who are involved, affected and primary users are engaged. It is important to engage stakeholders as they help to execute other steps.

ii) Describe the program

This is where the stakeholders set the references in terms of need, expected effects activities, resources, stage of development, context and logic model.

iii) Focus the evaluation design

This involves direction and process of evaluation in terms of purpose, users, uses, questions, methods and agreements.

iv) Gather credible evidence

This is where people involved in an evaluation collect information to convey a well-rounded picture of the program in terms of indicators, sources, quality, quantity and logistics.

v) Justify conclusions

Evaluation conclusions are justified when they are linked to the evidence gathered and judged against agreed-upon values or standards set by the stakeholders. Conclusions are on basis of evidence includes the following five elements: standards, analysis and synthesis, interpretation, judgment, recommendations.

vi) Ensure use and share lessons learned

It should not be assumed that lessons learned in the course of an evaluation will automatically translate into informed decision-making and appropriate action. Therefore, deliberate effort is needed to ensure that the evaluation processes and findings are used and disseminated appropriately. Preparing for use involves

strategic thinking and continued vigilance, both of which begin in the earliest stages of stakeholder engagement and continue throughout the evaluation process. The following five elements are critical for ensuring use: design, preparation, feedback, follow-up, dissemination.

vii) Standards for Effective Evaluation

The second element of the framework involves a set standard which are approved for assessing the quality of evaluation which are in four groups; Utility, Feasibility, Propriety and Accuracy. The standards help to assess whether a set of evaluative activities are well-designed and working to their potential.

All the steps in the framework for program evaluation were incorporated in a different way in the development of the study framework. They were all tailored to reduction of silica dust and chemical irritants. The standards in proposed study framework were all the legal frameworks on occupational health and safety in section 2.2. The legal frameworks were used as the standards in the developed framework.

2.5.2 Spectrum of Prevention Framework

Spectrum of Prevention framework promotes a multifaceted range of activities for effective prevention. It is used on prevention initiatives such as traffic safety, violence prevention, injury prevention, nutrition, and fitness. It can however be used for other disciplines (Cohen and Swift, 1999). This framework has six levels for strategy development namely: influencing policy and legislation, changing organizational practices, fostering coalitions and networks, educating providers, promoting community education and strengthening individual knowledge and skills.

i) Influencing policy and legislation

Changes in local laws and other policies have the potential for achieving the broadest impact on the prevention of any health concern across a community. Effective formal informal policies lead to behaviour change and change in social norms.

ii) Changing organizational practices

Changing organization practices encourages or improves the health of the members. Examining the practices of key organizations, such as law enforcement, health departments, health and safety of the greater community. This is usually as a result of change in the legislation. This is why it is critical that legislation is changed in line with prevention of a particular health concern.

iii) Fostering coalitions and networks

For an initiative to be successful, participants have to come together through collaborative approaches, brings together the participants necessary to assure an initiative's success. Coalitions are good tools for public health movements including injury prevention. They also reduce competitions among individual participants have the ability to help accomplishing abroad goals that reach beyond the capacity of any individual member organization.

iv) Educating providers

It is important that providers receive education in their field of expertise in order to improve their understanding so that they transmit information and skills in their colleagues and clients.

v) Promoting community education

A community education approach aims to reach groups of people with information and resources for improving health. This is done through mass media and brochures. This is important in that it helps individuals to be alert and also encouraged group support in injury or diseases prevention. This can also be done by the experts who were educated as providers.

vi) Strengthening individual knowledge and skills

Strengthening individual knowledge and skills involves transferring information and knowhow to increase an individual's resources and capacity for preventing injury or disease. This means that professions and experts in particular field of interest have to educate individuals in trying to bring awareness of prevention of injuries or diseases.

From the spectrum of prevention framework, the area of interest in the development of the study framework were influencing policy and legislation, changing organizational practices, fostering coalitions and networks, promoting community education and strengthening individual knowledge and skills.

2.5.3 Strategic Prevention Framework (SPF)

Strategic Prevention Framework (SPF) was developed by the Center for Substance Abuse Prevention (CSAP) which is the part of the Substance Abuse and Mental Health Services Administration (SAMHSA) of the U.S. Department of Health and Human Services (Anderson-Carpenter et al., 2016). The SPF involves a process that an organisation can use to prevent and reduce the use and abuse of alcohol, tobacco and drugs. The framework can be used for other community concerns. It has five comprehensive community based steps namely; assessment, capacity, planning, implementation and evaluation which work in concert to promote cultural competency and sustainability of community-based prevention efforts.

i) Assessment

Assessment involves the identification of information on the prevention needs. Local preventive needs and resources are identified in line with how ready the group is in solving the problem.

ii) Capacity

This involves building capacity in the participating group in terms of knowledge and skills through training to help in solving the prevention need.

iii) Planning

Planning involves creating objectives and how they would be achieved using some action strategies. This is where resources are mobilised such as financial and human resources.

iv) Implementation

Implementation involves the carrying out of the objectives that were planned. Practical strategies are executed involving all the stakeholders.

v) Evaluation

Evaluation involves review of the all process to analyse if what was planned was actually carried out and if the goals were realised or achieved. The results evaluation is used to adjust the program in order to improve the prevention outcomes. The lessons learned are then incorporated in the cycle.

All the five steps in the strategic prevention framework were incorporated in the development of the proposed framework. However, they were all tailored to suit the preventive strategies from the findings of the study and the literature review.

2.5.4 Development of the Proposed Integrated Framework for the study

The three frameworks framework for program evaluation, spectrum of prevention framework and strategic prevention framework were integrated and used in the development of the proposed framework for the study. The three frameworks were tailored to the occupational health and safety requirements from findings and literature review and also to suit the Zambian construction industry.

The stakeholder involvement was key even in the validation of the developed framework as it was learned from the three reviewed frameworks that when stakeholders are involved they help in the execution of other steps. Therefore, the developed framework has stakeholder involvement from inception to the last stage according to their duties and what they are mandated to do by government in the construction industry. Moreover, the stakeholders were also selected to help with the validation of the framework model because they were experts. The stakeholders who took part in the validation process were experts or involved in occupational safety and health and safety. Experts were from academia, health and safety professionals, government agencies responsible in the construction industry and occupational health and safety, engineers, clients and contractors as these form part of the project team.

The developed framework is in line with the project cycle so that it fits in what already exist in the construction industry. This is for easy adaptation and the standards that were incorpates in the developed framework were international standards; Promotional Framework for Occupational Safety and Health Convention,

2006 (No. 187) and the OSHA PELs and the OHS, Act of 2010, Factories Act; the ZEMA, Act; Public Health Act; the NCC Act; Workers compensation Act; and Mines and Minerals Development Act as local standards. These standards relate to occupation health and safety and silica dust and chemical irritant hazards.

2.6 Critique of the Reviewed Literature

There are many studies that have been conducted on the silica dust and chemical irritant exposures in the construction industry. Several of these studies have focused on either silica dust or chemical irritants singularly. On silica dust exposures, studies have focused on the exposure levels, controls for reduction of exposure and prevalence of the respirable diseases. Likewise, on the chemical irritants, the focus has been on the prevalence of skin diseases. There are few studies with the focus on both silica dust and chemical irritants like one by Saji et al. (2018) who did an epidemiological study on effect of occupational exposure of cement in India. In Nigeria, Ugbogu et al. (2009), focused on occurrence of respiratory and skin problems among manual stone-quarrying workers. There is no known study, to the researcher's knowledge, that has been focused on the silica dust and chemical irritants collectively for construction specialised workers in both road and building sectors in Zambia. Nsunge (2019) focused on respirable dust and occurrence of respirable symptoms among the road construction workers. Moreover, Nsunge (2019) did not measure the silica concentration in the respirable. It was critical to find the concentration of silica dust in the construction industry in Zambia and to find solutions of mitigating exposures to silica dust and chemical irritants.

However, Zambia has only the recommended legal limit for dust which was being monitored by Zambian mining industry regulatory authority under the Mine Safety Department (MSD) specifically in the mines. The MSD uses konimeter dust count which does not account for the percent of silica content in the dust. This research is focused on silica dust and chemical irritants because they are related in terms of construction materials that produce the hazards. Silica content materials in their wet state produce chemicals that are irritable to the skin and in their dry state produce silica dust during grinding, cutting, sanding and other construction activities. One such example of construction material is concrete. In its wet state, it poses chemical

irritant hazards and in its dry state, produces silica dust when it is being worked on through activities like cutting and grinding.

The summary of the critique of reviewed literature is presented in Table 2.2.

2.7 Contribution of the research to Literature

This study contributes important knowledge of silica dust concentration experienced in construction industry in Zambia. Also the preventive strategies through the developed integrated preventive framework. In this research silica dust concentration construction personnel were exposed to was established and it was above the OSHA PEL. The research findings, literature review on the control methods and the reviewed frameworks contributed towards development of an integrated preventive framework for construction personnel who are exposed to both silica dust and chemical irritants. The framework was developed to reduce exposure levels to silica dust and chemical irritant hazards in the construction industry in Zambia. Several studies have been done on silica dust in construction in developed and developing countries. However, very little had been done on the two hazards combine that is silica dust and chemical irritants in construction in one study. Moreover, the research filled the gap of silica exposure levels in terms of concentrations and the situation of chemical irritant exposures experienced by construction specialised personnel in Zambia which had not been studied before.

Table 2.2: Literature Review Matrix

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
1	Esmail and Sakwari, 2021	Occupational Skin Diseases among Building Construction Workers in Dar es Salaam, Tanzania.	To assess the prevalence of occupational skin diseases, associated factors and preventive measures among building construction workers in Dar es Salaam, Tanzania.	The Nordic Occupational Skin Questionnaire (NOSQ).	There was 54% prevalent of skin diseases. Carpenters had a higher prevalence of skin diseases (67%), Assistant masons (64%). Provision of safety trainings, PPE utility and guidance lowers skin diseases occurrence. The paper shows high prevalence of skin diseases in construction and emphasised administrative control and PPE use.
2	Nsunge, 2019	An assessment of Dust Exposure Levels and Factors Associated with the Occurrence of Respiratory Symptoms Among Workers in the Road Construction Industry in Lusaka, Zambia.	The study assesses dust exposure levels and factors associated with the occurrence of respiratory symptoms among road construction workers in Lusaka district in Zambia.	Personal dust samplers, American thoracic health questionnaire and Spirometry test.	Prevalence of respiratory symptoms were; nose irritation (59%), wheezing (45%) phlegm 29% and shortness of breath (39%). Mean exposure level was 1.77mg/m ³ which was above the Zambian TLV (1.74mg/m ³). The study gives a foundation for the situation of respirable dust and prevalence of symptoms of respirable diseases in the road construction sector in Zambia. Also the idea of lung function test to find out the workers lung function.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
3	Nirmala and Prasad, 2019	Occupational hazards and public health concerns of migrant construction workers: an epidemiological study in southern India.	To study the socio demographic profile and morbidity profile among construction workers.	Semi structured questionnaire.	The prevalence of respiratory problems was high among construction workers. The prevalence was 26% and may have been as a result of increased dust, paint and allergens. The common complaints were coughing and difficulties in breathing.
4	Li et al., 2019	Investigation of dust exposure and control practices in the construction industry in Hong Kong: Implications for cleaner production.	To formulate an initial list of construction process producing high levels of dust. To test the amount of dust generated and investigate measures implemented for dust control.	Interviews, focus group and personal air sampling (NIOSH 06000 and 7500).	Cement mixing machines, marble cutters and processes; cement mixing, concrete breaking and manual demolition produced higher silica exposures, above 15% silica content. Controls; LEV, blower fans and wet method.
5	Saji et al., 2018	An epidemiological study on effect of occupational exposure of cement	To realize the health hazards among dry (cement transporting labourers) and wet cement (construction workers) exposed group and effect of duration of exposure to cement.	Questionnaire survey and personal observations.	The prevalence of symptoms has direct correlation with the nature of work and prolonged exposure to cement and results in lower respiratory functions. Throat irritation and sneezing were associated to high exposure. Burning was the most observed in concrete mixer (70%).

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
6	Kabir et al., 2018	An investigation into respiratory health problems of workers at stone crushing industries in Bangladesh.	To investigate the respiratory problems among stone crushing workers in Bangladesh.	Cross-sectional-questionnaires, in-depth-interviews and spirometric examinations.	Chronic dust exposure increases the risk of respiratory diseases as there is a significant relationship between dust inhalation and respiratory diseases. Silica dust levels were not measured.
7	Timmerman, 2017	Contact Dermatitis in the Construction Industry.	To assess the current prevalence of contact dermatitis, discover risk factors and develop a prognostic tool for occupational physicians to detect it early in the Dutch construction industry.	Self-reported and doctor-diagnosed, self-administered questionnaires/photograms	The prevalence of Contact dermatitis was 25.5%, dust exposure was one of the risk factors. This study identifies exposure to dust as the risk factor in construction and relates it to skin disease (dermatitis).
8	Mashqoor et al., 2017	Occupational Skin Diseases in Construction Workers at a Large Construction Site.	To see the type of skin diseases among construction workers at large construction site.	Physical examination and laboratory tests.	Contact dermatitis was the most common, other diseases include fungal infection, scabies and acne. The paper supports the fact that skin diseases are prevalent in construction.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
9	Bedoya-Marrugo et al., 2017	Conditions of Work and Dermatitis in Workers Exposed to Chemical Risks by Cement.	The research identifies the working conditions in workers exposed to cement in a cement factory and to establish measures trending to ensure the complete state of health of workers.	Questionnaire survey, observations, narrations, written records (n=30).	Appearance of dermatitis is directly proportional to period of exposure to cement. Cement components cause lesions in workers and eventually leads to dermatitis. The preventive measures include training on hazards, proper use of cement, hygiene measures, proper use of PPE and reduction in the period of worker exposure to cement. The paper brings out the relationship between occurrence of skin diseases and the period of exposure to cement (chemicals).
10	Mohamed et al., 2017	Determination of crystalline silica in respirable dust upon occupational exposure for Egyptian workers.	To investigate the occupational exposure to crystalline silica dust in Egypt.	Personal dust samples n= 47 in 22 factories according to MDHS 14/3 & NIOSH method 7602 at 2.2 L/min was used for 60-120 minutes.	Silica dust concentrations in all the 22 factories were much higher than the allowable limit. This study gives insight of high silica exposure in several industries including construction as some activities sampled are part of construction.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
11	Normohammadi et al., 2016	Risk Assessment of Exposure to Silica Dust in Building Demolition Sites.	To determine the amount of workers' exposure to crystalline silica dust in building demolition sites and assess the relative risk of silicosis mortality and the excess lifetime risk of mortality from lung cancer in building demolition workers.	Personal air sampling was performed according to NIOSH Method 7601 for silica dust, at 1.7 L/min flowrate was used for full-shift.	80% of workers were exposed to silica dust more than the TLV. GM was 0.13mg/m ³ and AM was 0.19mg/m ³ . Risk of silicosis increased with higher exposures (1-22.64/1,000 employees), 32-60/1,000 for lung cancer. The paper reveals the that workers in construction are exposed to silica dust levels higher than the allowable limit and are at high risk of developing silicosis.
12	Kirkeskov et al., 2016	Total and respirable dust exposures among carpenters and demolition workers during indoor work in Denmark.	The paper assess if there were differences in dust exposure between carpenters and demolition workers who were expected to have low and high dust exposure, respectively.	Personal dust sampling for RCS was determined gravimetrically. The RCS was analysed according to NIOSH method 7602.	The exposure to dust is higher for demolition workers compared to carpenters. This study gives insights in understanding that different specialised workers experience different silica dust exposure and this is important in establishing controls.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
13	Wu et al., 2016	Mitigating construction dust pollution: state of the art and the way forward	To generalize the development of construction dust regulations, to investigate the main sources and corresponding countermeasures of dust pollution at jobsite and recommend for mitigating construction dust pollution at municipal level in China.	Content analysis, on-site observation, interviews, questionnaire survey and case study.	Sources of dust on site were earth excavation, land levelling, backfilling, and transportation of soil/construction waste, blasting demolition. Use of ready-mix to avoid onsite making of concrete, adherence to regulations to avoid high fines were recommended. The paper gives the sources of dust on construction sites and how to mitigate dust.
14	Bhuiyan et al., 2015	Pattern of occupational skin diseases among construction workers in Dhaka city.	To assess the prevalence and pattern of dermatoses among construction workers.	Physical examination, laboratory tests and questionnaire survey.	Prevalence of skin diseases was 59.5%, contact dermatitis was most common. The study gives the prevalence of skin diseases in construction.
15	Timmerman et al., 2014	Skin Symptoms in the Construction Industry: Occurrence and Determinants.	To determine prevalence of skin symptoms in the construction industry and to assess possible risk factors and determinants.	Questionnaire survey.	Prevalence of skin symptoms was 25.4% among construction workers. Dust exposure was the most important work-related determinant for symptoms.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
16	Radnoff and Kutz, 2014	Exposure to Crystalline Silica in Abrasive Blasting Operations Where Silica and Non-Silica Abrasives Are Used.	To describe results from 2011 exposure monitoring studies that included worker exposure in abrasive blasting operations where both silica sand and silica substitutes were used.	Silica dust samples for respirable were collected (full shift) and analysed according to NIOSH Method 7500 and OSHA Method ID-42.	Evaluation of the potential for exposure to crystalline silica is required even when silica substitutes are used as they do not reduce exposure below the allowable limit. The paper presents one of controls in the hierarchy of controls which is substitution method as one method that contributes to reduction of silica dust exposure.
17	Ahmed and Abdullah, 2012	Dust Exposure and Respiratory Symptoms among Cement Factory Workers in the United Arab Emirates.	To assess cement dust exposure and its relationship to respiratory symptoms among cement workers	Personal dust samples for total dust was determined gravimetrically and analysed according to NIOSH method 5000, interviews and questionnaires were also used.	Total dust ranged from 4.20 mg/m ³ to 15.20 mg/m ³ and most of samples were above exposure limit (10mg/m ³). The prevalence of respiratory symptoms was higher among the exposed workers. There was a relationship between dust exposure levels and symptoms of respirable diseases (cough and phlegm). The study reveals the relationship between levels of exposure and symptoms of respirable diseases.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
18	B.-J. Wang et al., 2011	Occupational hand dermatitis among cement workers in Taiwan.	To investigate the severity of occupational cement contact dermatitis and the common allergens among cement workers in Taiwan.	Structured questionnaire patch testing.	Cement hand dermatitis was important and severe; Potassium Dichromate and thiuram mix were most allergens. The study presents construction chemicals that cause skin diseases.
19	Shah and Tiwari, 2010	Occupational Skin Problems in Construction Workers.	To find the prevalence of skin problems among unorganized construction workers.	Interviews and Clinical skin examination.	The prevalence of skin symptoms was 47.8%. The paper presents the problem of skin diseases in construction.
20	Ugbogu et al., 2009	Occurrence of respiratory and skin problems among manual stone-quarrying workers.	The paper ascertains the nature of the parent rock material and to establish if there is a positive relationship between the manual stone quarrying and occurrence of symptoms of respiratory diseases and skin dermatoses.	Questionnaires and elemental analysis and silica content of parent rock.	There was a relationship between dust inhalation and the respirable diseases and skin diseases. The paper reveals that one hazard (dust particles) can cause symptoms of both respirable and skin diseases.
21	Fourie et al., 2008	Epoxy Resin Exposure and Dermatitis– A Case Study.	Highlighting complexities of assessing skin reactions to epoxy resins.	Patch tests.	Exposure to epoxy causes occupational contact irritant and allergic dermatitis. The study presents the effects of chemical irritants on the workers skin in construction.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
23	Yassin et al., 2005	Occupational Exposure to crystalline silica dust in the United States, 1988-2003.	The study summarizes and updates measurements of crystalline silica dust exposure levels among U.S workers and to estimate the number of workers who are exposed to silica in industries inspected by OSHA.	Personal measurements of silica exposure collected between 1988 and 2003 using OSHA method ID-142 for quartz.	Despite the decline in silica exposure levels during 1988 -2003, some industries were still overexposed (3.6%). The paper gives the need for more concerted effort in mitigating silica dust.
24	Croteau et al., 2004	The Efficacy of Local Exhaust Ventilation for Controlling Dust Exposures During Concrete Surface Grinding	The study assesses the efficacy of LEV for controlling surface grinding dust exposures in the field setting.	Personal samples of respirable and silica dust were collected on surface grinders with LEV and without LEV using NIOSH method 0600 for respirable dust and NIOSH 7602 for silica dust.	The LEV reduced silica exposure by 92%. Reduction may be more if used in combination with other controls. This study presents insights in silica dust controls that one method cannot reduce exposure below the PEL but the combination of several methods does.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
25	Rappaport et al., 2003	Excessive Exposure to Silica in the US Construction Industry.	To find which trade is overexposed to dust and silica dust and the controls used in the US construction Industry.	Reports of institutions that conducted air sampling using NIOSH 7500.	Painters were overexposed to silica dust (1.28mg/m ³). Painters were performing abrasive blasting that is why they had higher exposures. This study supports the fact that specialised workers are exposed to different silica dust levels depending on the activities.
26	Flanagan et al., 2003	Silica Dust Exposures During Selected Construction Activities.	To provide a more comprehensive evaluation of exposure to silica during common dust-producing construction activities, to identify factors that are important in affecting exposure levels, and to characterize exposure for non-contiguous tasks.	Quartz and respirable dust exposure n= 113 samples for selected activities using both time-integrating filter samples and direct-reading respirable dust monitors.	Quartz concentration was 0.10 mg/m ³ for all run time samples, 71% exceeded the threshold limit value (0.05 mg/m ³). Activities with the highest exposures were surface grinding, tuck-point grinding, and concrete demolition. Important factors to exposure were; tool used, work area configuration, controls employed, cross draft, and in some cases nearby dust. The study brings out the important factors that affect exposure as these are critical in mitigating silica dust exposures.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
27	TjoeNij et al., 2003	Dust control measures in the construction industry.	To evaluate the impact of control measures for reducing quartz dust exposure and to assess the extent of their use.	Respirable dust sampling (n = 61), full-shift among construction workers and a questionnaire survey n= 1335 construction workers were used.	Respirable quartz exposure levels up to 63 times the MAC and more than 50% of measurements were above the MAC of 0.075 mg/m ³ . Control measures were strongly associated with the short-term measurements and showed >70% reduction factors compared to the full-shift exposures when wet dust suppression or local exhaust ventilation was used. Combination of controls showed 99% reduction. The study gives insights in the importance of full shift measurements when dealing with exposure reduction methods and the significance of combining control methods.
28	Tae et al., 2002	Level of Silica in the Respirable Dust Inhaled by Dental Technicians with Demonstration of Respirable Symptoms.	To measure level of respirable dust and silica content in the respirable dust generated from dental laboratory, and to compare occurrence of respiratory symptoms in dental workers with that of non-dental hospital workers, as the control.	Respirable dust sampling was performed according to 0600 NIOSH Method at flowrate of 1.7 L/min for 6 hours.	The silica concentration was 0.0508mg/m ³ which was slightly more than 0.05mg/m ³ OSHA PEL. Silica content was 1.66% of the dust. This study shows that other industries that use similar activities to construction have comparable silica dust exposures.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
29	TjoeNij et al., 2002	Pneumoconiosis and Exposure to Quartz-containing Dust in the Construction Industry.	To characterize dust and quartz exposure as part of a cross-sectional study on pneumoconiosis among construction workers.	Respirable dust sampling (n = 61), full-shift among construction workers and a questionnaire survey n= 1335 construction workers were used.	Mixed dust type of pneumoconiosis (ILO category $\geq 1/1$, irregular opacities) was observed in 2.9% of workers. Exposure measurements showed quartz levels between 0.002 and 3.77 mg/m ³ . The study shows high silica dust exposure which are related to pneumoconiosis in workers.
30	Lumen and Spee, 2001	Determinants of Exposure to Respirable Quartz Dust in the Construction Industry	To investigate the level of silica exposure for several jobs, and to determine the contribution of different determinants to total exposure at construction sites.	Personal air sampling, direct reading dust monitor, (NIOSH 7500), questionnaire and checklist were used to collect data.	The overall GM was 0.5mg/m ³ and above limit of 0.075mg/m ³ . GM for demolition workers was 1.1gm/m ³ . Work practice, working environment, process and appliances, agents were the determinants for exposure.

S/N	Author(s)	Title	Objectives	Methodology	Conclusions/Comments
31	Thorpe et al., 1999	Measurements of the Effectiveness of Dust Control on Cut-off Saws Used in the Construction Industry.	To quantify the benefits of control systems in silica dust exposures.	Respirable dust sampled using MDHS 14 for onsite and laboratory environment without and with controls.	Without control cut-off saws produced high respirable silica dust levels. Both LEV and the proper application of water reduced levels significantly (90%) but each control individually could not reduce exposure below 0.4mg/m ³ . This paper supports the effectiveness of combination of controls in silica dust reduction below the allowable limit.

2.8 Theoretic Framework of the Study

A theoretic framework is a structure that can support a theory of a research. A theory is a well-established principle that has been developed to explain some aspect of the natural world (Cohen and Pate, 2019). Theories arise from repeated observation and tested hypotheses that are widely accepted (Frodeman, 2010). This research integrated the Theory of Work Adjustment and Domino Safety theory in relation to the reduction of silica dust and chemical irritants for specialised construction workers in Zambia.

2.8.1 Theory of Work Adjustment

Theory of work adjustment is also known as Person-Environment Correspondence (PEC) theory, describes the relationship the individual has with the work environment with the goal of job retention (Dahling and Librizzi, 2015). The more closely a person's abilities correspond with the requirements of the organisation, the more likely it is that they would perform the job well and be perceived as satisfactory by the employer. In the same way, the more closely the reinforcers (rewards) of the organisation correspond to the values that a person seeks to satisfy through their work, the more likely it is that the person would perceive the job as satisfying (Dawis, 2005). There are six work reinforce values; achievement (accomplishment), autonomy (initiative and self-control), altruism (harmony and service for other), safety (environment free from stress), comfort (stability and predictability) and status (recognition). There are three outcomes of successful work adjustment which are satisfactoriness, satisfaction and tenure. However, unsuccessful work adjustment means that correspondence no longer exists. This results in an employee leaving the job or termination by an organization. Before separation occurs, there are four variables that help with the interaction; flexibility, perseverance, activeness and reactiveness. Flexibility is the range of discorrespondence an individual or environment can accept before termination while perseverance is the length of time an individual or environment can persist. Activeness is the action taken to change the environment whereas reactiveness is the action taken to change an individual or self (Dawis and Lofquist, 1984).

In relation to this research, the specialised personnel may choose active adjustment by demanding that management provides proper silica dust and chemical irritants

controls such as PPE to protect them from exposure to silica dust and chemical irritants. Moreover, they may demand that other controls especially the hierarchy of controls are put in place to reduce levels of exposure. However, some specialised workers may choose reactivity by finding alternatives to protect themselves from high exposures like buying their own gloves and respirators or use controls that they can manage within their means. The importance of PEC Theory in this research is focused on understanding how specialised construction personnel interact with their work environment that has silica dust and chemical irritant hazards and how the organization responds to reduction or mitigation of such hazards so that the personnel are protected from high exposures that cause symptoms of respirable and skin diseases.

2.8.2 Domino Safety Theory

Domino Safety Theory was initially developed in 1929 by Herbert William Heinrich and was later revised by Bird and Loftus in 1974. The theory was revised because it placed the blame of accident causation on a worker. Therefore, the changed theory included the role of management in accident causation. According to Sabet et al. (2013), the revised Domino theory focuses on process contributing to accident occurrence from general worker to managers. Organisations should ensure that they work on unsafe acts and unsafe conditions to avoid losses (Sabet et al., 2013).

There are five dominos. The following are the five Dominos and their meaning in this research.

- i) Social environment- Management (legal frameworks, exposure control plan, health and safety policy and plan).
- ii) Personal Characteristics (fault of a person) example recklessness- workers' behaviour or response.
- iii) Unsafe acts and unsafe conditions- exposure to silica dust and chemical irritants due to lack of proper reduction controls from the hierarchy of controls.
- iv) Incidents- workers inhale silica dust and skin gets in contact with chemical irritants during the work activity or task.
- v) Injury-workers develop symptoms of respiratory and skin diseases.

This research focuses on the updated Domino accident causation theory (Birds, 1974). Management (underlying cause) and basic cause are important in prevention of the immediate cause, contact and loss. The immediate cause means exposure to silica dust and chemical irritants while working on silica dust and chemical irritants producing activities. Contact means workers' inhale silica dust or workers skin being in contact with the chemical irritants due to exposure while loss means occurrence of symptoms of respiratory and skin diseases among workers. Table 2.3 shows how the Dominos were used in the research.

Table 2.3: Application of Domino Theory in the Research

Domino	Domino Theory by Heinrich (1929)	Updated Domino Theory by Birds (1974)	In this research
1	Social environment & Ancestry	Underlying cause (Management)	Company management (legal frameworks, exposure control plan, health and safety policy and plan)
2	Fault of a person	Basic cause (Origin)	Workers' behaviour or response
3	Unsafe acts and Unsafe conditions	Immediate cause	Exposure to silica dust and chemical irritants
4	Accident/incident	Incident (Contact)	Workers inhale silica dust and skin comes into contact with chemical irritants
5	Injury	Loss (people/property)	Workers develop symptoms of respiratory diseases and skin diseases

2.8.3 Integration of Theory of Work Adjustment and Domino Safety Theory

The two theories have been integrated as shown in Figure 2.1. The main interests from the theory of work adjustment is correspondence which is the relationship between workers and the environment. In the absence of correspondence, there is active and reactive adjustment which is the reaction of workers. In the Domino safety theory, the research focuses on the Dominos 1, 2 and 3. It is expected that when Dominos 1,2 and 3 are dealt with correctly, Dominos 4 and 5 are prevented.

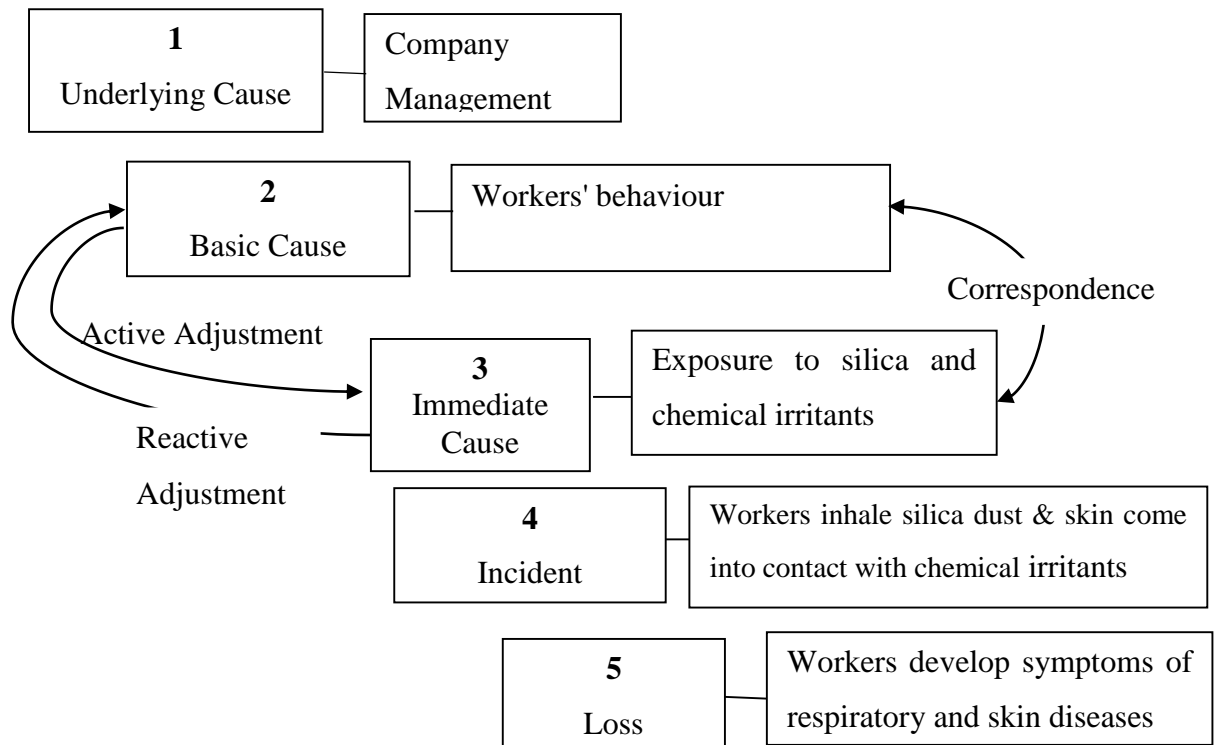


Figure 2.2: Theoretical Framework

2.9 Conceptual Framework of the Study

A conceptual framework is a visual or written product that explains either graphically or in narrative form, the main things to be studied, the presumed relationship among key factors, concepts, or variables (Miles et al., 2014). The conceptual framework gives a guide of what is going on and why the phenomenon is taking place (Maxwell, 2012).

The conceptual framework of the study was informed by the integration of two theories namely; theory of work adjustment describes the relationship the individual has with the work environment (Dahling and Librizzi, 2015). In this case, the domino number 3, unsafe acts and unsafe conditions are the immediate cause which are exposure to silica dust and chemical irritants as given in the theoretical framework of the study. It is the exposure to silica dust and chemical irritants that the study is focused on. When exposure to silica dust and chemical irritants are prevented, it means that domino number 4 which is incident, is prevented, thereby mitigating the symptoms of respiratory and skin diseases that are caused by the exposure. Therefore, silica dust and chemical irritants exposure cause the symptoms of

respiratory and skin diseases. Silica dust and chemical irritants exposure are the independent variables and symptoms of respiratory diseases are the dependent variables.

The integrated preventive framework that the study seeks to develop comes in to prevent the symptoms by mitigating the exposure levels above OSHA PEL for silica dust and levels and period of exposure for chemical irritants. Literature review on previous studies informed the independent variables, mediating variables and independent variables of the study. Several studies have shown that silica dust levels above $0.05\text{mg}/\text{m}^3$ (Li et al., 2019; Mohamed et al., 2018; Kirkeskov et al., 2016; Normohammadi et al., 2016; Hayumbuet al., 2008) affect the workers' health by causing symptoms of respiratory diseases such as chronic obstructive pulmonary disease, renal disease, tuberculosis, lung cancer and silicosis (Li et al., 2019; Normohammadi et al., 2016). On the other hand, previous scholars found that exposure to chemical irritants in terms of levels of exposure and period of exposure affect the symptoms of skin diseases such as dermatitis and eczema (Esmail and Sakwari, 2021; Bedoya-Marrugo et al., 2017; Moshqoor et al., 2017; Bhattarai et al., 2015).

The conceptual framework for the study is shown in Figure 2.3. In this study, it is assumed that construction site personnel are exposed to silica dust and chemical irritants that harm and lead to symptoms of respiratory and skin diseases respectively. Since it is a cross sectional research, the focus is on the exposure to silica dust and chemical irritants and symptoms of respiratory and skin diseases. Therefore, the independent variables in this research were levels of silica exposures, dust levels and silica dust controls for silica dust exposures while for chemical irritant exposures were levels of exposures, period of exposures and controls. According to Creswell (2014), independent variables are variables that affect the outcome. The dependent variables were prevalence of symptoms of respiratory and skin diseases as they were the outcomes. Dependent variables are the outcome of the independent variables (Creswell, 2014). There were no moderating variables in this research because everything was assumed to be constant during the dust sampling which was part of experimental data collection. Moderating variables are

independent variables that influence the relationship between the independent variable and the dependent variable (Vij and Farooq, 2017).

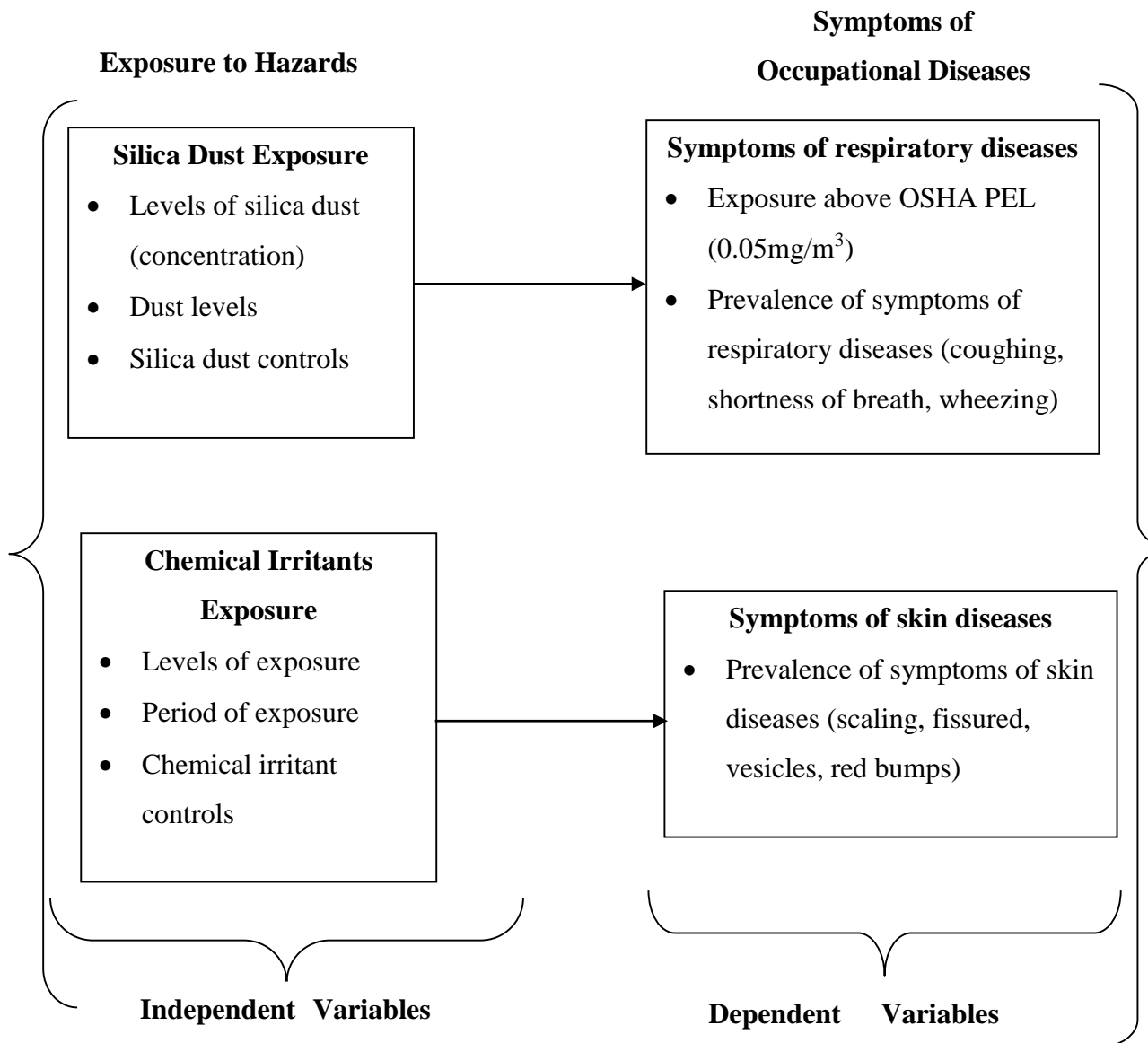


Figure 2.3: Conceptual Framework

2.10 Hypotheses of the Research

Hypothesis is a prediction, empirical and testable statement that the study is trying to find (Anupama, 2018). The null hypothesis which is denoted as H_0 , is a typical theory which suggests that there is no statistical relationship. The alternative hypothesis which is denoted as H_A , is a statement the hypothesis test is set up to establish. It is the opposite of null hypothesis. The following were the research hypotheses.

H_{N1}: The levels of silica dust construction specialised personnel were exposed to were not above OSHA PEL (0.05mg/m³).

H_{A1}: The levels of silica dust construction specialised personnel were exposed to were above OSHA PEL (0.05mg/m³).

H_{N2}: The dust levels were not related to prevalence of symptoms of respirable diseases.

H_{A2}: The dust levels were related to prevalence of symptoms of respirable diseases.

H_{N3}: The levels of exposure to chemical irritants for construction specialised personnel in Zambia were not related to prevalence of symptoms of skin diseases.

H_{A3}: The levels of exposure to chemical irritants for construction specialised personnel in Zambia were related to prevalence of symptoms of skin diseases.

H_{N4}: The period of exposure to chemical irritants for construction specialised personnel in Zambia was not related to prevalence of symptoms of skin diseases.

H_{A4}: The period of exposure to chemical irritants for construction specialised personnel in Zambia was related to prevalence of symptoms of skin diseases.

H_{N5}: The controls used for silica dust were not related to prevalence of symptoms of respiratory diseases.

H_{A5}: The controls used for silica dust reduction were related to prevalence of symptoms of respiratory diseases.

H_{N6}: The controls used for chemical irritants were not related to prevalence of symptoms of skin diseases.

H_{A6}: The controls used for chemical irritants were related to prevalence of symptoms of skin diseases.

H_{N7}: A developed integrated preventive framework cannot reduce exposure to silica dust and chemical irritants among specialised site construction personnel in Zambia.

H_{A7}: A developed integrated preventive framework can reduce exposure to silica dust and chemical irritants among specialised site construction personnel in Zambia.

2.11 Summary

Literature was reviewed on legal frameworks that are used in the construction industry internationally and locally in relation to silica dust and chemical irritants and their effects. Studies on silica dust and chemical irritant exposures in the construction industry and the related symptoms of respirable and skin diseases were also reviewed. The different controls in the hierarchy of controls for silica dust, the research theories and how the independent variables related with the dependent variables in the conceptual framework was addressed.

The following chapter give the methodology that was used in the research, how the data was collected, analysed and interpreted to address the aim and the objectives.

CHAPTER 3: METHODODOLOGY

3.1 Introduction

The preceding chapter presented the literature that was reviewed on previous studies in line with the research title and objectives. Chapter three gives the research paradigms and the design. It also presents the methodology, data collection and analysis techniques and research ethical issues. This research took the pragmatist position where positivists and constructivists principles were used (Creswell, 2014) thus multiple methods of data collection and analysis were employed.

3.2 Research Paradigms

A paradigm is a philosophical stance of the research that deals with beliefs and understandings. Paradigms consist of ontology, epistemology and methodology (Scotland, 2012).

3.2.1 Ontology

Ontology is the branch of philosophy which is concerned with being and what exists (McQueen and McQueen, 2010). There are two types of ontological positions, namely; objectivism and constructivism.

(a) Objectivism

Objectivism asserts that social phenomenon and their meanings have an existence that is independent of social actors (Bryman, 2008). This is used in quantitative approach.

(b) Constructivism

Constructivism asserts that social phenomenon and their meanings are continually being accomplished by social actors. According to Scotland (2012), reality is individually constructed and there are as many realities as individuals. Constructivism is used in qualitative approach.

In this research, both the ontological stances of objectivism and constructivism were used. Objectivism assumes that there are some realities that are independent of social factors such as;

- (i) The OSHA PEL for silica dust ($0.05\text{mg}/\text{m}^3$) and respirable dust ($5\text{mg}/\text{m}^3$).

- (ii) Methods of dust sampling and analysis; MDHS101/2 for RCS and MDHS14/4 for respirable dust samples.
- (iii) Five methods of control of silica dust and chemical irritants (hierarchy of controls).

Constructivism stance which assumes that phenomenon and their meanings are continually being accomplished by social actors, in this research, constructivism was used in the research theory. The research theory integrated the Theory of work adjustment and the Domino Safety Theory. This was mainly based on the relationship between workers and the environment (management and the working environment) in terms of silica dust and chemical irritants exposures and controls.

3.2.2 Epistemology

Epistemology is the branch of philosophy which is concerned with knowledge and how we can come to know things (McQueen and McQueen, 2010). There are two types of epistemological positions, namely positivism and interpretivism.

(a) Positivism

Positivism asserts that social research should try by all means to emulate scientific methods. According to Scotland (2012), positivistic statements should be descriptive and factual. Positivism deals with establishing a relationship between two variables through hypothesis testing.

(b) Interpretivism

Interpretivism asserts that meaning is constructed through the interaction between consciousness and the world (Scotland, 2012).

This research adopted positivism epistemological stance where the hypotheses for the research were tested for significance using statistical analysis. On the other hand, the research took the interpretivism stance on observed research issues on how the workers were relating with the environment such as levels of exposure to dust and chemical irritants, symptoms of skin diseases, existing controls used in the industry for silica dust and chemical irritant exposures and workers' behaviour during work activities which were done through observations and photographs.

3.3 Methodology

Methodology is concerned with how the knowledge would be known. Crotty (1998), describes methodology as a plan of action on how to use specific methods. In this research Case Study-Mixed Method design was selected and Mixed method approach was used. Mixed methods involve the use of quantitative and qualitative methods. Methods are procedures used to collect data related to research questions or hypothesis (Creswell, 2014). The research employed qualitative and quantitative methods that were used simultaneously. Under quantitative method, silica dust sampling instruments and questionnaire surveys were used. Qualitative data that were used were observations and photographs. Sampling was done on the construction specialised personnel on a road and building projects. Before the data was collected, ethical approval was done by Natural and Applied Sciences Research Ethics Committee (NASREC). Finally, quantitative data was analysed using SPSS using inferential and descriptive statistics. Qualitative data was analysed using constant comparative method.

3.3.1 Research Design

The Case Study Mixed Method –Convergent design or according to Creswell (2014) it can be referred to as Case Study-Convergent Parallel Mixed Method design was used in this research. This involved selection of two cases then the mixed methods were used on the two cases. The design was used to merge qualitative and quantitative data for understanding the cases. The two cases; the construction of a road and a building project were selected to properly answer research questions and objectives. Two case studies were used as case studies provide unique examples of real people in a real situation (Cohen, 2000). The results from both qualitative and quantitative were compared and were interpreted convergently or divergently. The results were used in the establishment of the preventive framework. The framework was validated using quantitative methods by construction health and safety experts in the form of questionnaires. The research design is as shown in Figure 3.1. Kindly note that the arrows in Figure 3.1 simply mean feeds into.

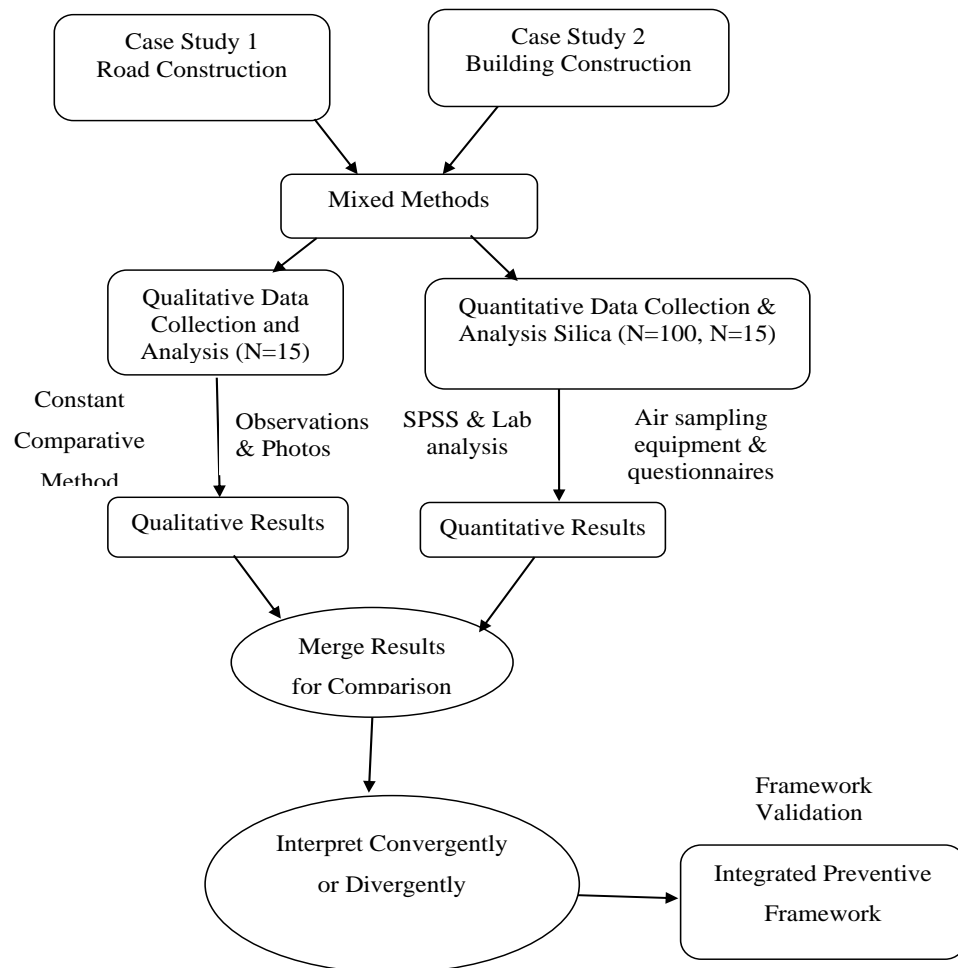


Figure 3.1: Research Design

3.3.2 Research Approaches

According to (Creswell, 2014) there are three research approaches namely qualitative, quantitative and mixed methods approaches.

(a) Quantitative Approach

In quantitative research approach, the researcher uses positivists world view of testing hypotheses and uses statistical methods of data analysis.

(b) Qualitative Approaches

The researcher uses constructivist and transformative world views in qualitative approach. This helps in seeking the phenomenon meaning or examining oppression related issues respectively.

(c) Mixed Methods approach

This uses pragmatic world view where both quantitative and qualitative data is collected to understand the problem. In mixed methods approach there is generalization of results.

In this research, mixed method approach was utilised where experimental method of silica dust sampling, questionnaire surveys and observation using observation schedule and camera for photographs were used. In addition, quantitative data was analysed statistically, and hypothesis were tested while qualitative data was analysed by constant comparative method.

3.3.3 Population

The target population for the study were workers who were prone to silica dust exposure and chemical irritants. The actual total population of the workers in question was not known as they kept employing in stages as a result of Ministry of Health Covid-19 Prevention Guidelines. Moreover, the workers were reduced in numbers because of Covid-19. Therefore, 1,012 was an estimated population for both the building and the road projects.

The road project was the Lusaka City Decongestion Project and building project was the Construction of INDO Zambia Bank Headquarters in Lusaka. The two case studies were selected to get the experience of existing exposure levels on both roads and building projects. This also helped in comparing the exposure levels in the two projects. In addition, this was important as the results helped in the development of an integrated preventive framework which would be used in the construction industry as a road and a building projects were a good representation of the construction industry.

3.3.4 Sampling

Purposive sampling and random sampling were used in the study. Purposive sampling is the method of selecting participants who are highly likely to display the process being examined. Despite the use of a questionnaire survey, the purposive sampling was adopted in this research after thorough literature review on the previous studies which have established that there are specific skilled or workers in

the construction industry who are more exposure to silica dust and chemical irritants. If sampling included all the workers even those who are exposed to low silica dust exposures, findings would underestimate true exposure levels as part of the study was to establish if silica dust exposures construction workers experience were above OSHA PEL of $0.05\text{mg}/\text{m}^3$. Therefore, in this research, the workers who were identified in literature review as the workers who are more exposed to silica dust and chemical irritants, were purposively sampled.

a) Questionnaire survey phase one

Construction workers such as bricklayers, carpenters, batchers, tilers, demolition workers, painters, handymen and road construction workers were purposively sampled and then randomly selected. The construction personnel who are more exposed to crystalline silica and chemical irritants were deduced from literature review. The workers were verified on sites with the help of site supervisors. The sample size was established at 10% of the estimated population (Martínez-Mesa et al., 2016). Moreover, the sample size of 100 was selected using a conventional method and is justified by previous study that supports that the sample size of 45 and above is enough for construction-related research for the questionnaire survey (Fellows and Liu, 2008). In addition, the sample size was limited to 100 because of Covid-19 restrictions which led to downsizing the workforce on both the building and road projects as a directive preventive measure from Ministry of Health. Therefore, the sample size was $n=100$. An interview-based questionnaire was conducted on 100 workers, among which observation and photos were randomly taken. The questionnaires were divided equally between the road and the building project to get the equal coverage.

b) Air sampling measurement

The workers who were working on the dust activities were purposively sampled to be part of the air sampling measuring. The silica dust samples were initially planned to be 30 in total for both road and building projects. This sample size is similar to Gottesfeld et al. (2019) who had the sample size $n = 29$ in their study in Nigeria. In addition, the sample size for the air sampling was 30 because the silica dust sampling media which were 25mm PVC filters, cassettes and cyclones, were hired from NIOH South Africa and shipped back for analysis. This is because there was no laboratory

in Zambia for silica dust analysis at the time the research was being conducted. Despite planning for 30 samples, 15 from building and the other 15 from the road project, silica dust sampling was only taken from the building project. This was because the road projects were discontinued as a result of the heavy rains. Therefore, the total number of silica dust samples were 15. Sampling was done by the researcher with the help of a technician from Mines Safety of Zambia this is because they provided the Casella Apex2 pumps. The sampling for the silica dust was planned for three of tilers, three bricklayers, three carpenters, three painters and three demolition workers. Nevertheless, during the data collection, labour had been reduced on site. Consequently, the researcher managed to collect data from four tilers, four bricklayers, five carpenters, two painters and one demolition worker as these were the available labour during the time of data collection for silica dust sampling.

c) Questionnaire survey phase two

The construction experts were purposively sampled in the framework validation because they were either occupational safety and health specialists or were part of the project team. The targeted number of experts to help in the validation process was 20. The experts were sampled from academia, consulting engineers, private and public clients, contractors and government institutions who were in charge of construction and occupational safety and health.

3.3.5 Ethical Considerations

The data was collected upon getting official permission from site managers and receiving consent from the respondents. Most importantly the respondents were also assured of confidentiality of the names of the respondents and that the information that they gave would only be used for academic purpose. Each respondent had to sign the consent certificate to show their willingness to participate in the research. They respondents were guaranteed to discontinue with the research anytime if they were not comfortable. Moreover, the respondents were assured of privacy of the data as it would be kept under lock and key until it is properly disposed off. The overt observation was selected to ensure that consent is given. Therefore, pictures that were taken have no faces and were approved by respondents. The NASREC ethical requirements were followed. Ethical clearance was approved by NASREC on 31 May 2021 with the approval number NASREC:2021-MARCH-010.

3.4 Research Methods

Research methods involve the ways of collecting data, analysing data and interpreting data (Creswell, 2014).

3.4.1 Data Collection Techniques and Instruments

The research involved the two types of data collection techniques namely primary and secondary data. The primary data was quantitatively and qualitatively collected. Quantitative data was collected both from quantitative data was collected using questionnaires and personal air sampling pumps to measure silica dust exposure levels. Qualitative data was collected using observation schedule and the Tecno Canon 17 phone camera for photographs.

a) Secondary Data Collection Technique

The secondary data was collected from literature review on the previous studies on silica dust and chemical hazards, exposure levels, symptoms of respiratory and skin diseases, and controls in construction. The secondary data helped in setting the base for the study. Different sources were used to review literature such as books, articles, journals, conference proceedings, legal frameworks, guidelines, reports, theses and internet. The review of relevant literature was presented in chapter two. The literature which was reviewed helped in examining the different methods of silica dust sampling and analysis that exist. Additionally, research methods of data collection and analysis which were used in previous studies similar to this research were reviewed. Literature review also aided in establishing a gap which this research seeks to fill.

The resulting theory that was used in this research was an integration of Domino Safety Theory and Theory of Work Adjustment as presented in section 2.8.3. The review of literature informed the research theory as Domino Safety Theory and Theory of Work Adjustment were reviewed to come up with the research theory. Furthermore, the basis for the design of the questionnaires was from literature review. The research problem was established after literature review as a void which needed to be filled. The review of relevant literature was presented in chapter two. Relevant literature review gave an insight of both international and local research findings on the topic. However, few research was conducted on both the silica dust

and chemical irritants in one study. This is important because construction staple materials that contain silica become chemical hazards in their wet state and produce silica dust in their dry state during some construction activities. No research has been done in the construction industry in Zambia to address exposures and mitigating measures for both hazards and to specifically establish the silica dust concentration the workers are exposed to in relation to the OSHA PEL of 0.05mg/m³.

b) Primary Data Collection Technique

The primary data collection technique is the collecting of first-hand information by the researcher using data collecting instruments such as interviews, questionnaire and experiments (Creswell, 2014). Primary data can be collected quantitatively and qualitatively.

i) Quantitative Data Collection Instruments

Air sampling media and questionnaires were to collect quantitative data.

Silica Dust Sampling Media

Personal air sampling pumps measured silica dust levels. Personal samples of respirable crystalline silica dust was collected at a flow rate of 2.2 L/min with a battery-operated Casella Apex2 sampling pump. The pump was attached to the employee's waist and connected through a tubing to a pre-weighted 25-mm, 5- μ m pore size polyvinyl chloride (PVC) filter in a filter cassette. A 25-mm nylon cyclone was placed in the employee's breathing zone below the collarbone with the inlet pointing downwards. The MDHS14/4 for respirable dust samples and MDHS101/2 for RCS were used for sampling. The sampling for silica dust was done using 8-hour TWA. The silica dust sampling was conducted in the period of two weeks from the start of sampling.

Questionnaire

An interview- based questionnaire was administered face to face as some workers were not able to read and write and also to avoid taking much time as the works on both sites were behind schedule. The questions in the questionnaire were semi structured and closed ended questions. There were two open ended questions which targeted at letting the respondents give their suggestions or opinions on how best silica dust and chemical irritants exposures could be reduced and eventually prevent

the symptoms of respirable and skin diseases. The questionnaire was accompanied by a letter of permission to carry out the research. This letter stated the purpose of the data and the issues of confidentiality. For the purposes of this research, the existing site conditions were maintained to get the real challenges faced by the workers. The information collected was stored under lock and key. Silica dust measurements was collected after the questionnaire survey.

ii) Qualitative Data Collection Instruments

The qualitative data was collected using observation schedules and camera.

Observation Schedule and Camera

Overt and direct observations were used. Overt observation is when participants are aware that they are being observed (Lugosi, 2006). This was used to ensure that ethical issues were adhered to according to the ethical clearance approval by Natural and Applied Sciences Research Ethics Committee (NASREC). Observation was used as a check against respondents' subjective reporting in the questionnaires. Moreover, observations revealed interactions between workers and management in terms of control measures in silica dust and chemical irritants exposure reduction. One of the disadvantages of observation is that it is time consuming (Creswell, 2014). However, this was mitigated by collecting quantitative and qualitative data simultaneously.

The observations were conducted all through data collection and was intensified when silica dust measurement was being done as it had to take eight hours for a full shift from start to finish per sample. In addition, some days were purely set for observation as both sites were behind schedule and could only allow to administer questionnaires on selected days. Observations were accompanied by the visual material from photographs which were taken using Techno Canon 17 phone camera (6.6"-720x1600 pixels). According to Pain (2012), photographs are used in data collection to get appropriate tacit data for providing cues for understanding the topic. In this research, photographs were used to complement what was being observed. In this case text from the observations and photographs enhanced meaning to the data (Johnson, 2004). Photographs were taken with the consent of the participants. In addition, assurance was given to the participants by the researcher that faces would

be avoided and only capture the activity or interest of observation according to NASREC ethical approval.

3.4.2 Bias

Biasness in the research was mitigated by the use mixed methods of quantitative and qualitative. Quantitative methods involved experimental and questionnaire survey while observation was under qualitative methods.

3.4.3 Validity

Validation deals with the accuracy of a measure or scrutiny of well-founded argument and empirical evidence to determine if they support the theoretical claims (Taylor, 2013). The dust sampling instruments which included a pump, 25mm PVC filters, cassettes and cyclones were calibrated before use. Calibration validates an equipment. The sampling and analysis methods of MDHS14/4 and MDHS101/2 are international standardised methods (HSE, 2005; HSE, 2014). According to Taylor (2013), for research that use positivism as the philosophical stance, statements are valid if they fit in the logical systems that explain reality. Therefore, the calibrated sampling instruments and the standardized sampling and methods used in the research were valid.

During the questionnaire survey, a pilot study was conducted as a way to pre-test the questionnaire on 10 skilled workers. This was done for content validity purposes. The questions that were not clear to the skilled workers were simplified and corrected accordingly. Other questions and statements that seemed to be out of context were removed. Validation of the observation method was confirmed in the use of other methods which were the air sampling and the questionnaire survey. This was a form of triangulation in this research as three methods were used.

For the purposes of validity of data analysis, constant comparative method and SPSS while interpretation was done through hypothesised relationship and theoretical constructs. Hypothesized relationships and probabilistic statements are considered valid as they give predictive power and the probabilities are clear in advance (Taylor, 2013).

3.4.4 Reliability

Reliability deals with consistency of the measure (Creswel, 2014). The measure of internal consistency which measure reliability was established by calculating Cronbach’s alpha coefficient. Cronbach’s alpha coefficient ranges from 0 to 1 and the closer the coefficient is to 1, the higher the reliability. The Cronbach’s alpha coefficient was calculated as shown in equation one.

$$\alpha = \frac{N \bar{c}}{\bar{v} + (N-1) \bar{c}} \dots\dots\dots\text{Equation One}$$

Where;

N = the number of items.

\bar{c} = average covariance between item-pairs.

\bar{v} = average variance.

Cronbach’s alpha for experimental results and phase two questionnaire results were 0.87 and 0.702 respectively. Using the interpretation of the Cronbach’s alpha coefficient as presented in Table 3.1, the experimental results were good and phase two questionnaire results were acceptable.

Table 3.1: Cronbach's Alpha Rule of Thumb

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Phase one questionnaire responses were similar to what was obtained from the overt observations. This means that questions in the phase one questionnaire were similar to what was in the observation schedule. Therefore, phase one questionnaire results were reliable according to inter – item reliability (Gliem and Gliem, 2003).

3.4.5 Data Analysis and Interpretation

The data which was collected was analysed according to the type of data. The qualitative data was analysed using constant comparative method. The quantitative data was analysed using IBM SPSS version 1.0.0.45 by means of descriptive and inferential statistics.

For quantitative data, Pearson Chi-square and degree of freedom were used to test the degree of association between the independent and dependent variables. The level of significance of $p < 0.05$ and confidence interval of 95% were considered as statistically significant. For the results to be statistically significant under One-Sample Test, the following should be met;

- Using the Degree of Freedom (df) and the two-tailed in the Student's t Distribution Table, the found Critical Value CV should be less than the t in the One-Sample Test.
- The p value should be less than 0.05.
- The 95% confidence interval should not cross the zero.

i) Air Sampling Data

The MDHS14/4(HSE, 2014) by gravimetric method and MDHS101/2 (HSE, 2005) by X-ray diffraction (XRD) were used for analysis for respirable dust samples and the RCS respectively. The silica dust sampling media was hired from NIOH laboratory in South Africa who also did the analysis of the samples. The NIOH XRD laboratory is a South African National Accreditation System (SANAS) Accredited laboratory with the accreditation number T0660. The laboratory report is attached in the appendix. The Limit of Detection (LOD) for gravimetric was 0.007 and for XRD was 0.005. The Limit of Quantification (LOQ) for gravimetric was 0.024 and for XRD was 0.018. The uncertainty for gravimetric was 0.27% while for XRD was 2.15%. The volume of sampled air was calculated using the flow rate of 2.2L/Min and the duration of sampling was 8 hours (480 min) and divided by 1000L in order to convert litres to cubic metres (m^3) as shown in equation Two. The concentration of respirable dust and RCS were calculated in mg/m^3 as shown in equation three and four respectively.

$$V_s (\text{m}^3) = \text{Flowrate (L/Min)} \times \text{Time (Min)} / 1000 \text{L} \dots \dots \dots \text{Equation Two}$$

Where;

V_s = Volume of sampled air (m^3)

$$\text{Respirable Dust Concentration (mg/m}^3\text{)} = M_f \text{ of filter (mg)} / V_s (\text{m}^3) \dots \dots \dots \text{Equation Three}$$

Where;

M_f = final mass of respirable dust (mass of filter plus cassette after sampling minus mass of filter plus cassette before sampling minus average mass of blanks) which was done by gravimetric.

V_s = Volume of sampled air in m^3 .

$$\text{RCS Concentration (mg/m}^3\text{)} = M_{\text{RCS}} (\text{mg}) / V_s (\text{m}^3) \dots \dots \dots \text{Equation Four}$$

Where;

M_{RCS} = final mass of RCS done by XRD.

V_s = Volume of sampled air in m^3 .

The Arithmetic Mean (AM) and Geometric Mean (GM) for concentrations were calculated for all the measures and for each job title. One Sample Test was performed on the respirable and RCS concentrations to test the first hypothesis using OSHA-PELs concentrations of 5mg/m^3 and 0.05mg/m^3 respectively. In addition, cross-tabulations between the levels of exposures to respirable and RCS and job title were done to establish the relationship.

ii) Questionnaire Survey Data

Descriptive and inferential statistics were used to determine the levels of exposure, prevalence of the symptoms of respirable and skin diseases, levels and period of exposure to chemical irritants and the controls used for the exposures. Cross-tabulations were performed to establish relationships between levels of exposures to silica dust and chemical irritants and symptoms of respirable and skin diseases. An independent sample test was also conducted to establish the relationship between dust exposure levels and type of construction in terms of building and roads sectors.

iii) Observation Data

The qualitative data from observations were analysed using Constant Comparative Method (Saunders et al., 2007). The information from photos were presented together with observation results to support what was observed.

iv) Framework Model Data

To validate the framework model, a 5-point Likert scale was used, where strongly disagree was 1, disagree was 2, not sure was 3, agree was 4 and strongly agree was 5 (Joshi et al., 2015). This measure of agreement was used to get the opinion of experts on the developed framework model. The 5-point Likert scale was selected in this research because it is simple to understand by both the researchers and respondents. Moreover, it takes less time and effort to complete. For the purposes of analysis, the mean range and the scale similar to Bringula et al. (2012) was adopted and the result similar to Alonazi et al. (2019) was used despite the opposite scale as presented in Table 3.2. The mean score was calculated according to equation five.

Table 3.2: 5 Point Likert Scale and its Interpretation

Scale	Result	Mean Range	Interpretation
5	Strongly agree	4.51 - 5.0	Very important
4	Agree	3.51 - 4.50	Important
3	Not sure	2.51 - 3.50	Moderately important
2	Disagree	1.51 - 2.50	Unimportant
1	Strongly disagree	1.00 - 1.50	Very unimportant

$$\text{Mean score} = \frac{\sum O_x}{\sum R_x} \dots\dots\dots \text{Equation Five}$$

Where;

O_x = number of option x (1,2,3,4,5) per question or statement.

R_x = number of respondents who selected option x.

Therefore, any mean score above 3.50 was considered important and was used to test the significance using One-Sample Test.

3.5 Summary

The paradigms and the methodology of the research were presented. The ontological stance which was used was objectivism and constructivism whereas the epistemologically, the positivism stance was used where the hypotheses were tested

for significance using statistical analysis. Moreover, the Interpretivism stance was used during observations. Further, chapter three gave the ways that were used for data collection, analysis and interpretation. Three methods were adopted to collect data were; experimental- use of silica dust sampling media, questionnaires-interview based questionnaire in the first phase and self-administered questionnaires in the second phase, and overt observations were observation schedule and camera were used. The next chapter presents the results the research results.

CHAPTER 4: RESULTS PRESENTATION

4.1 Introduction

This chapter presents the research findings from the questionnaires, observation schedule, photographs and silica dust sampling equipment. The questionnaire survey, photographs and observations were conducted between May and November 2021 on a road project and a building project as case studies. Silica dust sampling was conducted in January 2022 on the building project. This is because there were serious rains and roadworks were on hold because of too much water. This resulted in only taking the silica dust samples on the building project where the works were mainly indoors. The questionnaire respondents who were purposively sampled were carpenters, bricklayers, handymen, demolition workers, painters, batchers and road construction workers. Observations, photographs and silica dust measurements were done on some of the sampled questionnaire survey respondents.

4.2 Profile of Respondents

The respondents were nine women and 91 men. All the nine women were from a road project. Five of the women were handywomen and three were road construction workers who included flaggers and manual sweepers. Of the nine women, three handywomen and one road construction worker were below 25 years; two road construction workers were between 26 and 36 years and two handywomen and one road construction worker were between 36 and 45 years. Silica dust sampling, observations and photos were conducted on the same questionnaire respondents.

4.3 Silica Dust Sampling Results

The MDHS14/4 and MDHS101/2 methods were used for analysis for respirable dust samples and the RCS respectively. The dust samples were received on 11 March 2022 and were analysed on 14 March 2022. The flow rate of 2.2L/Min and the 8h-TWA (480min) were used to calculate the volume of sampled air (1,056L). The volume of sampled air was then used to calculate the concentrations. There were two samples that were not analysed for RCS as the comment was that there was loose dust left in the cassette. To ensure that the results were fit to be used in SPSS, the missing results for RCS were calculated using the average silica content (6.82%) for the other 13 samples which were analysed. This was arrived at after looking at the maximum measurement for RCS ($0.446\text{mg}/\text{m}^3$) from the 13 analysed samples which

was 82.7% higher than the OSHA PEL of 0.05mg/m³. The RCS concentrations for the missing measurements were 1.048mg/m³ for the concentration of 15.370mg/m³ of respirable dust and 1.582mg/m³ for the concentration of 23.192mg/m³ of respirable dust. One-Sample Test in SPSS was done on the concentrations to find statistically if they were above the OSHA PELS of 5mg/m³ and 0.05mg/m³ for respirable dust and RCS respectively. Moreover, cross-tabulations were performed to find if there was a relationship between the exposure levels and job title.

4.3.1 Silica and Respirable Dust Exposure Levels

The results for concentrations are presented in Table 4.1. The highest individual concentration for silica dust was 1.582mg/m³ which is 96% higher than OSHA PEL. The overall GM for all the job titles for RCS dust was 0.04mg/m³ which is 20% less than OSHA PEL of 0.05mg/m³. The overall AM for all the job titles for RCS was 0.228mg/m³ which is 0.178 (78%) more than OSHA PEL of 0.05mg/m³.

Table 4.1: Exposure Levels for Respirable Dust and Respirable Crystalline Silica Dust

Job Title	RD (mg/m ³)	RCS (mg/m ³)	Silica Content (%)	RD (GM) (mg/m ³)	RD (AM) (mg/m ³)	RCS (GM) (mg/m ³)	RCS (AM) (mg/m ³)
Tiler Handyman	0.599	0.020	3.32	0.335	0.496	0.010	0.055
Tiler	0.342	0.062	18.01				
Tiler	0.545	0.082	2.91				
Bricklayer Handyman	0.553	0.016	6.64	0.251	0.313	0.007	0.008
Bricklayer Handyman	0.325	0.004	2.24				
Bricklayer	0.295	0.007	11.25				
Bricklayer	0.078	0.007	8.54				
Carpenter Handyman	15.370	1.048	15.10	3.239	8.725	0.195	0.627
Carpenter	3.964	0.446	3.64				
Carpenter	0.770	0.051	8.95				
Carpenter	0.328	0.008	8.54				
Carpenter	23.192	1.582	4.28				
Painter	0.442	0.016	2.31	0.464	0.464	0.026	0.030
Painter	0.487	0.044	8.95				
Demolition Worker	0.687	0.029	1.46	0.687	0.687	0.029	0.029
Overall			6.8	0.779	3.198	0.04	0.228

The highest individual concentration for respirable dust was 23.192mg/m³ which is 78% higher than OSHA PEL (5mg/m³). The overall GM for all the job titles for Respirable Dust (RD) was 0.779mg/m³ which is 84% less than OSHA PEL of 5mg/m³. The overall AM for all the job titles for respirable dust was 3.198mg/m³ which is 36% less than OSHA PEL of 5mg/m³. The results showed that 40% of individual concentrations for RCS were above OSHA PEL (0.05 mg/m³) which included two tilers, carpenter handyman and two carpenters. The GM for RCS for tilers was 0.010mg/m³, bricklayers (0.007mg/m³), carpenters (0.195mg/m³), painters (0.026mg/m³) and demolition workers (0.029mg/m³). The AM for RCS for tilers was 0.055mg/m³, bricklayers (0.008mg/m³), carpenter (0.627mg/m³), painters (0.030mg/m³) and demolition workers (0.029 mg/m³).

The results showed that 13% of individual concentrations for RD were above OSHA PEL (5 mg/m³) for carpenter handyman (15.37mg/m³) and a carpenter (23.192mg/m³). The GM for RD for tilers was 0.335mg/m³, bricklayers (0.251mg/m³), carpenters (3.239mg/m³), painters (0.464mg/m³) and demolition workers (0.687mg/m³). The AM for RD for tilers was 0.496mg/m³, bricklayers (0.313mg/m³), carpenter (8.725mg/m³), painters (0.464mg/m³) and demolition workers (0.687 mg/m³).

The exposure levels for RCS and RD were recorded into high and low (above OSHA PEL as high and below OSHA PEL as low). The cross-tabulations between exposure levels and the job title showed that there was no relationship as the $p > 0.05$ for both RCS (0.105) and RD (0.290) as shown in Table 4.2 and 4.3 respectively.

The One-Sample Test was conducted in SPSS for RCS to test the first hypothesis to find out if the levels of silica dust construction specialised personnel in the construction industry in Zambia were above the OSHA PEL of 0.05mg/m³. The results showed statistically significance that RCS exposure levels were above the OSHA PEL of 0.05mg/m³ as shown in Table 4.4.

Table 4.2: Job Titles in relation to Respirable Crystalline Silica Dust Exposure Levels

Job Title	Frequency (%)	Silica Dust Exposure Levels		ρ-value
		Low N(%)	High N(%)	
Tiler Handyman	6.7	1(100)	0(0)	0.105
Tilers	13.3	0(0)	2(100)	
Bricklayer Handymen	13.3	2(100)	0(0)	
Bricklayers	13.3	2(100)	0(0)	
Carpenter Handyman	6.7	0(0)	1(100)	
Carpenters	26.7	1(25)	3(75)	
Painters	13.3	2(100)	0(0)	
Demolition Worker	6.7	1(100)	0(0)	

Table 4.3: Job Titles in relation to Respirable Dust Exposure Levels

Job Title	Frequency (%)	Respirable Dust Exposure Levels		ρ-value
		Low N(%)	High N(%)	
Tiler Handyman	6.7	1(100)	0(0)	0.290
Tilers	13.3	2(100)	0(0)	
Bricklayer Handymen	13.3	2(100)	0(0)	
Bricklayers	13.3	2(100)	0(0)	
Carpenter Handyman	6.7	0(0)	1(100)	
Carpenters	26.7	3(75)	1(25)	
Painters	13.3	2(100)	0(0)	
Demolition Worker	6.7	1(100)	0(0)	

Table 4.4: One-Sample Test for RCS Dust Using OSHA-PEL of 0.05mg/m³

	Test Value = 0.05					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
RCS	10.311	14	0.000	1.350	1.069	1.631

Using the df =14, at 95% confidence (0.05) and two-tailed, Critical Value (CV) was found as 2.145 in the student's t distribution table. The $t > CV$, $\rho < 0.05$ and at 95% confidence interval of the difference of lower = 1.069, upper = 1.63 did not cross the zero. Therefore, the result was statistically significant, and the null hypothesis was rejected.

In addition, One-Sample Test results showed statistically significance that RD exposure levels were above the OSHA PEL of 5mg/m³ as shown in Table 4.5. The

CV was 2.145 which was less than t (42.560), $\rho < 0.05$ and at 95% confidence interval of the difference of lower (-4.062), upper (-3.672) did not cross the zero, hence statistically significant.

Therefore, H_{N1} was rejected. This shows that the levels of silica dust specialised construction personnel are exposed to in Zambia were above OSHA PEL of $0.05\text{mg}/\text{m}^3$.

Table 4.5: One-Sample Test for RD Dust Using OSHA-PEL of $5\text{mg}/\text{m}^3$

	Test Value = 5					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
RD	-42.560	14	0.000	-3.867	-4.062	-3.672

4.4 Questionnaire Results

The data collected from questionnaires was analysed in SPSS using descriptive statistics. Pearson Chi-square and degree of freedom were used to test the degree of association between the independent and dependent variables. The level of significance of $\rho < 0.05$ and confidence interval of 95% were considered as statistically significant.

4.4.1 Silica Dust Exposure Levels

The questionnaire results showed that **all** the respondents experienced nuisance from dust during their work on site and **86%** of them experienced very high levels of dust exposures. The average means of levels of exposure to dust was **4.76** and **4.84** for road project and building project respectively. An independent sample test for levels of exposure to dust and type of construction was performed to find out which type of construction experienced higher levels. There was no significance between the levels of exposure to dust and the type of construction as shown in Table 4.6. The ρ -value was 0.133 which is greater than 0.05. In addition, the lower (-0.29) and upper (0.13) for 95% confidence interval of the difference crossed the zero which shows no significance.

Table 4.6: Independent Sample Test for Levels of Dust and Type of Construction

		Levene's Test for equality of variances		t-test for Equality of Means			
		F	Sig.	t	df	95% Confidence Interval of the Difference	
						Lower	Upper
Levels of exposure	(=)variances assumed	2.301	0.133	-0.75	98.0	-0.29	0.13
	(≠)variances assumed			-0.75	93.08	-0.29	0.13

The dust levels which was a scale variable (low, average, high and very high), was recorded in to an ordinal variable (low, average and high) then used in the cross tabulations to establish the relationships with other variables. The profile of respondents in relation to the dust exposure levels is shown in Table 4.7. The ρ -values for gender, age, type of construction, job title and years of experience were greater than 0.005 for significance hence there was no relationship.

The average means for the symptoms of respirable diseases was less than the average median indicating the measure of distortion of symmetric to the left (negative skewness) as shown in Table 4.8. All standard deviations were within $\pm 2SD$ indicating that values were closer to the true value.

The cross tabulation results presented in Table 4.9, between the levels of exposure to dust and prevalence of symptoms of respirable diseases shows no statistical relationship. The p-value was 0.117 which is more than p-value of 0.05 for significance, Pearson Chi-square was 5.892 and degree of freedom (df) of 3. Therefore, H_{N2} was accepted. The levels of exposure to chemical irritants for construction specialised personnel in Zambia were not related to prevalence of symptoms of skin diseases.

Table 4.7: Profile of Respondents in relation to the Levels of Dust Exposures

Characteristics	Frequency (%)	Dust Exposure Levels		p-value	
		Average N(%)	High N(%)		
Gender					
Male	91	6(7)	85(93)	0.427	
Female	9	0(0)	9(100)		
Age (Years)					
≥ 25	21	1(5)	20(95)	0.924	
26 ≥ 35	40	3(8)	37(92)		
36 ≥ 45	26	1(4)	25(96)		
46 ≥ 55	10	1(10)	9(90)		
>55	3	0(0)	3(100)		
Type of Construction					
Road Project	50	4(8)	46(92)	0.400	
Building Project	50	2(4)	48(96)		
Job Title					
Carpenters	8	1(13)	7(87)	0.661	
Bricklayers	36	2(6)	34(94)		
Painters	12	0(0)	12(100)		
Batchers	2	0(0)	2(100)		
Handymen	24	1(4)	23(96)		
Tilers	3	0(0)	3(100)		
Demolition Workers	4	0(0)	4(100)		
Road Construction Workers	11	2(18)	9(82)		
Years of Experience					
3≤5	56	2(4)	54(96)		0.460
3≤6	26	2(8)	24(92)		
>10	18	6(6)	94(94)		

Table 4.8: Comparison of Means Between Dust Levels and Symptoms of Respirable Diseases

Symptoms	Mean	N	Std. Deviation	Median	Skewness
Coughing	4.63	52	0.69	5.00	-1.64
Wheezing	5.00	30	0.00	5.00	
Shortness of breath	5.00	10	0.00	5.00	
None	4.88	8	0.35	5.00	-2.83
Total	4.80	100	0.53	5.00	-2.63

Table 4.9: Cross Tabulation of Dust Levels against Symptoms of Respirable Diseases

Dust Levels	Frequency (%)	Symptoms of Respirable diseases				p-value
		Coughing N(%)	Wheezing N(%)	Shortness of breath N(%)	None N(%)	
Average	6	6(100)	0(0)	0(0)	0(0)	0.117
High	94	46(40)	30(32)	10(10)	8(8)	

4.4.2 Prevalence of Symptoms of Respirable Diseases

The prevalence of the symptoms of respirable diseases was at 92%. The prevalence by type of symptoms is shown in Figure 4.1. Coughing was the most common as its prevalence was 52%. The relationship between the respondents' profile and the prevalence by type of symptoms of respirable diseases is presented in Table 4.10. Gender, age, type of construction and job title had a relationship with the prevalence of type of symptoms of respirable diseases as their ρ -values were less than 0.05 for significance. There was no relationship between years of experience and the prevalence of type of symptoms of respirable diseases because the ρ -value was greater than 0.05 for significance.

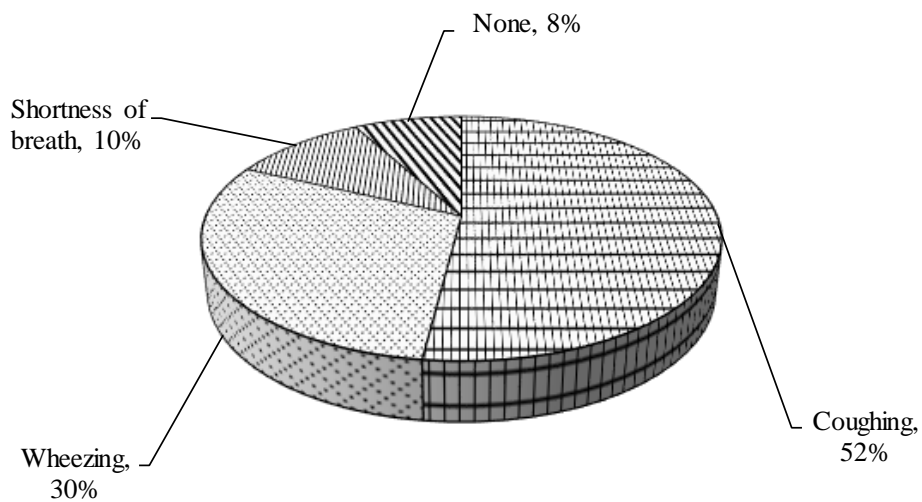


Figure 4.1: Prevalence of Symptoms of Respirable Diseases

4.4.3 Chemical Irritants Exposure Levels

According to the results, 85% experienced high levels, nine percent average and six percent low levels of chemical irritants. Dirty hands after work was associated to

Table 4.10: Profile of Respondents in relation to Symptoms of Respiratory Diseases

Characteristics	Freq (%)	Symptoms of Respiratory diseases				p-value	
		Coughing N(%)	Wheezing N(%)	Shortness of breath N(%)	None N(%)		
Gender							
Male	91	52(57)	30(33)	5(6)	4(4)	0.000	
Female	9	0(0)	0(0)	7(56)	4(44)		
Age (Years)							
≤ 25	21	13(62)	3(14)	2(10)	3(14)	0.008	
26 ≤ 35	40	20(50)	17(42)	2(5)	1(3)		
36 ≤ 45	26	15(58)	5(19)	4(15)	2(8)		
46 ≤ 55	10	4(40)	5(50)	0(0)	1(10)		
>55	3	0(0)	0(0)	2(67)	1(33)		
Type of Construction							
Road Project	50	34(68)	6(12)	5(10)	5(10)	0.001	
Building Project	50	18(36)	24(48)	5(10)	3(6)		
Job Title							
Carpenters	8	7(87)	1(13)	0(0)	0(0)	0.001	
Bricklayers	36	21(58)	14(39)	0(0)	1(3)		
Painters	12	1(8)	5(42)	5(42)	1(8)		
Batchers	2	2(100)	0(0)	0(0)	0(0)		
Handymen	24	12(50)	7(29)	3(13)	2(8)		
Tilers	3	3(100)	0(0)	0(0)	0(0)		
Demolition Workers	4	0(0)	3(75)	0(0)	1(25)		
Road Workers	11	6(55)	0(0)	2(18)	3(27)		
Years of Experience							
3≤5	56	30(53)	15(27)	6(11)	5(9)		0.926
3≤6	26	13(50)	10(38)	2(8)	1(4)		
>10	18	9(50)	5(28)	2(11)	2(11)		

exposure to chemical irritants. Therefore, 89% of respondents reported to have very dirty hands, nine percent a bit dirty and two percent as not dirty. The average means of levels of exposure to chemical irritants in the road and road construction was 4.34 and 4.6 respectively. The standard deviations were 1.04 for road and 0.86 for building construction which are within 95% of the data points falling within $\pm 2SD$. This means the values are closer to the true value and that the information can be predicted about the population. According to the independent sample test, there was no significance between levels of exposure to chemical irritants and type of

construction as shown in Table 4.11. The p-value was 0.051 which is more than p-value of 0.05 for significance. Moreover, the 95% confidence interval of -0.64 and 0.12 which crossed the zero, showed no significance.

Table 4.11: Independent Sample Test for Levels of Exposure to Chemical Irritants and Type of Construction

	Levene's Test		t-test for Equality of Means				
	F	Sig.	t	df	95% Confidence Interval of the Difference		
					Lower	Upper	
Levels of exposure	(=)variances assumed	3.92	0.051	-1.36	98.0	-0.64	0.12
	(≠)variances assumed			-1.36	94.5	-0.64	0.12

The levels of chemical irritants were recorded from scale variable (low, average, high and very high), in to an ordinal variable (low, average and high) then cross-tabulated with the profile of respondents to establish the relationships. The profile of respondents in relation to the levels of exposure to chemical irritants is shown in Table 4.12. The ρ -values for gender, age, type of construction, job title and years of experience in the industry were greater than 0.005 for significance hence there was no relationship.

4.4.4 Levels and Period of Exposure to Chemical Irritants in relation to Symptoms of Skin Diseases

All the means for the symptoms of skin diseases were less than the median indicating the measure of distortion of symmetric to the left (negative skewness) as shown in Table 4.8. There is a small range of standard deviations and they are all within $\pm 2SD$ indicating that values are closer to the true value. The recorded levels of exposure to chemical irritants were cross-tabulated and tested for significance. The high exposure level of was associated to scaly hands as shown in Table 4.13 and Table 4.14 which had the highest mean of 4.8. There was a statistical relationship between the levels of exposure to chemical irritants and prevalence of symptoms of skin diseases as Pearson Chi-square was 21.4 and df was 8, ρ -value was 0.006 which is less than 0.05, hence significant. This means that H_{N3} was rejected. Consequently,

the levels of exposure to chemical irritants for construction specialised personnel in Zambia were related to prevalence of symptoms of skin diseases.

Table 4.12: Profile of Respondents in relation to the Levels of Exposure to Chemical Irritants

Characteristics	Freq (%)	Chemical Irritants Exposure Levels			ρ-value
		Low N(%)	Average N(%)	High N(%)	
Gender					
Male	91	5(5)	7(8)	79(87)	0.254
Female	9	1(11)	2(22)	6(67)	
Age (Years)					
≥ 25	21	1(5)	3(14)	17(81)	0.341
26 ≥ 35	40	1(3)	2(5)	37(92)	
36 ≥ 45	26	3(12)	3(12)	20(76)	
46 ≥ 55	10	0(0)	1(10)	9(90)	
>55	3	1(33)	0(0)	2(67)	
Type of Construction					
Road Project	50	4(80)	6(12)	40(80)	0.375
Building Project	50	2(4)	3(6)	45(90)	
Job Title					
Carpenters	8	0(0)	2(25)	6(75)	0.343
Bricklayers	36	3(8)	2(6)	31(86)	
Painters	12	0(0)	0(0)	12(100)	
Batchers	2	0(0)	0(0)	2(100)	
Handymen	24	1(4)	2(8)	21(88)	
Tilers	3	0(0)	0(0)	3(100)	
Demolition Workers	4	0(0)	0(0)	4(100)	
Road Workers	11	2(18)	3(27)	6(55)	
Years of Experience					
3≤5	56	2(4)	6(11)	48(85)	0.569
3≤6	26	3(12)	1(4)	22(84)	
>10	18	1(6)	2(11)	15(83)	

Table 4.13: Comparison of Means Between Exposure Levels and Symptoms of Skin Diseases

Symptoms	Mean	N	Std. Deviation	Median	Skewness
Itchy hands with fissures	4.50	10	0.71	5.00	-1.18
Scaly hands	4.82	39	0.45	5.00	-2.59
Vesicles on the hands	4.45	11	0.82	5.00	-1.15
Red bumps on hands	4.56	18	0.98	5.00	-2.26
None	3.77	22	1.38	4.00	-0.75
Total	4.47	100	0.96	5.00	-1.92

Table 4.14: Cross Tabulation Between Exposure Levels and Symptoms of Skin Diseases

Chemical irritants Levels	Frequency (%)	Symptoms of Skin diseases					ρ -value
		Itchy Hands N(%)	Scaly Hands N(%)	Vesicles on Hands N(%)	Red Bumps on Hands N(%)	None N(%)	
Low	6	0(0)	0(0)	0(0)	2(33)	4(68)	0.006
Average	9	1(11)	1(11)	2(22)	0(0)	5(56)	
High	85	9(11)	38(45)	9(11)	16(19)	13(15)	

The common skin symptoms as already indicated was scaly hands and fingers. Moreover, the respondents who were exposed between three and eight hours experienced scaly hands more than those who were exposed for less than two hours and more than eight hours. The results from cross tabulation between period of exposure and occurrence of skin diseases in Table 4.15 shows that of all those workers who developed scaly hands or fingers, 49% were exposed between three and eight hours.

Table 4.15: Cross Tabulation Between Period of Exposure and Symptoms of Skin Diseases

Period of Exposure	Freq (%)	Symptoms of Skin diseases					ρ -value
		Itchy Hands N(%)	Scaly Hands N(%)	Vesicles on Hands N(%)	Red Bumps on Hands N(%)	None N(%)	
< 2 hrs	6	1(17)	2(33)	1(17)	0(0)	2(33)	0.023
3 ≤ 8 hrs	62	1(2)	30(49)	7(11)	12(19)	12(19)	
> 8 hrs	32	8(25)	7(22)	3(9)	6(19)	8(25)	

There was a statistical relationship between period of exposure to chemical irritants and occurrence of symptoms of skin diseases as Pearson Chi-square was 17.8, $df = 8$ and p-value of 0.023 which is less than p-value of 0.05 for significance. Thus, H_{N4} was rejected. This means that the period of exposure to chemical irritants for construction specialised personnel in Zambia was related to prevalence of symptoms of skin diseases.

4.4.5 Prevalence of Symptoms of Skin Diseases

The prevalence of symptoms of skin diseases was 78%. From the 78% prevalence, 39% was scaly hands, 18% was red bumps on hands, 11% was vesicles on hands and 10% was itchy hands as shown in Figure 4.2.

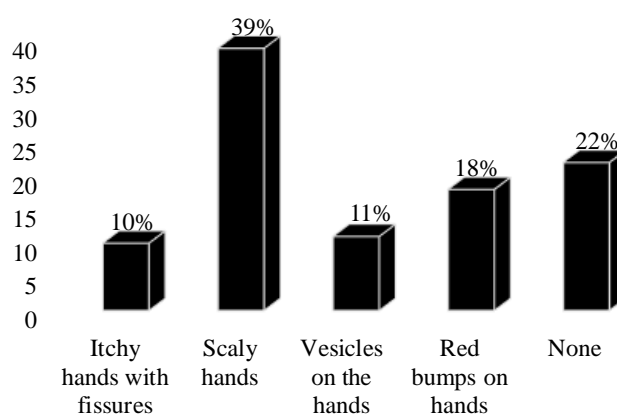


Figure 4.2: Prevalence of Symptoms of Skin Diseases

The relationship between the respondents' profile and the prevalence by type of symptoms of skin diseases is presented in Table 4.16. Gender and job title had a relationship with the prevalence of type of symptoms of skin diseases as their p -values were less than 0.05 for significance. There was no relationship between age, type of construction, years of experience and symptoms of skin diseases as their p -values were greater than 0.05 for statistical significance.

Of all the women respondents only two (22%) experienced symptoms of skin diseases and scaly hands in particular. Bricklayers Painters experienced symptoms of skin diseases (94%) more than other job titles while painters experienced scaly hands more compared to other job titles (67). Most respondents experienced symptoms of skin diseases more than thrice (54%) as shown in Figure 4.3.

Table 4.16: Profile of Respondents in relation to Symptoms of Skin Diseases

Characteristics	Freq (%)	Symptoms of Skin diseases					p-value	
		Itchy Hands N(%)	Scaly Hands N(%)	Vesicles on Hands N(%)	Red bumps N(%)	None N(%)		
Gender								
Male	91	10(11)	37(41)	11(12)	18(20)	15(16)	0.001	
Female	9	0(0)	2(22)	0(0)	0(0)	7(78)		
Age (Years)								
≥ 25	21	1(5)	8(38)	5(24)	1(5)	6(28)	0.065	
26 ≥ 35	40	3(8)	19(47)	4(10)	9(22)	5(13)		
36 ≥ 45	26	5(19)	8(31)	2(8)	3(11)	8(31)		
46 ≥ 55	10	1(10)	3(30)	0(0)	5(50)	1(10)		
>55	3	0(0)	1(33)	0(0)	0(0)	2(67)		
Type of Construction								
Road Project	50	3(6)	19(38)	8(19)	8(19)	12(24)	0.367	
Building Project	50	7(14)	20(40)	3(6)	10(20)	10(20)		
Job Title								
Carpenters	8	0(0)	3(37)	0(0)	2(26)	3(37)	0.046	
Bricklayers	36	2(6)	16(44)	7(19)	9(25)	2(6)		
Painters	12	0(0)	8(67)	0(0)	1(8)	3(25)		
Batchers	2	1(50)	1(50)	0(0)	0(0)	0(0)		
Handymen	24	4(17)	6(25)	3(13)	2(8)	9(37)		
Tilers	3	1(33)	1(33)	1(34)	0(0)	0(0)		
Demolition Workers	4	0(0)	2(50)	0(0)	2(50)	0(0)		
Road Workers	11	2(18)	2(18)	0(0)	2(18)	5(46)		
Years of Experience								
3≤5	56	5(9)	24(43)	8(14)	5(9)	14(25)		0.195
3≤6	26	4(15)	10(38)	2(8)	7(8)	3(12)		
>10	18	1(6)	5(28)	1(16)	6(33)	5(27)		

The symptoms of skin diseases mostly lasted within 3 weeks (71%) as shown in Figure 4.4. When respondents experienced symptoms of skin diseases, 57% of the respondents ignored and continued working, 19% were given some days off, 11% had to seek medical attention, eight percent were given lighter job tasks and five percent did not experience any symptoms.

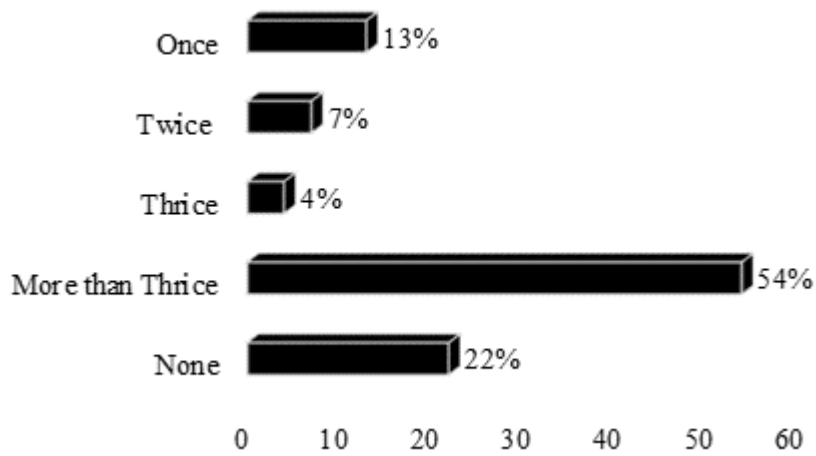


Figure 4.3: Frequency of Symptom of Skin Diseases

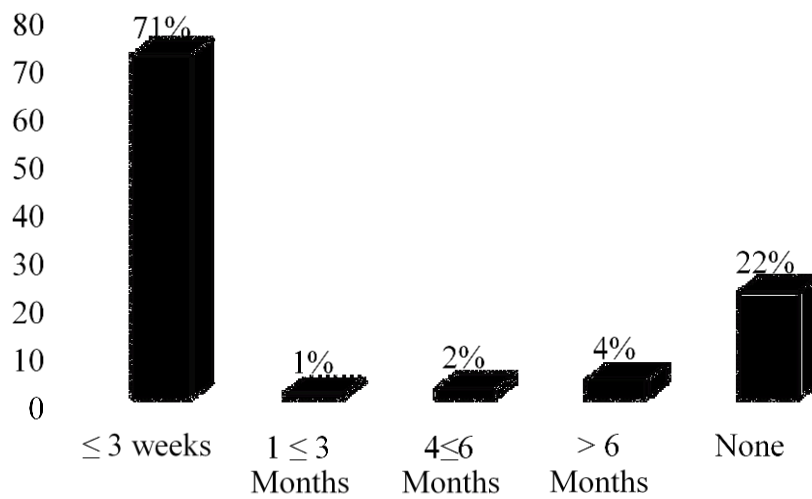


Figure 4.4: Duration of Symptoms of Skin Diseases

4.4.6 Controls Used on Sites for Silica Dust Exposure Reduction

The dust controls which were commonly used on sites were dust masks and water (52%) followed by dust masks only (24%) as shown in Figure 4.5.

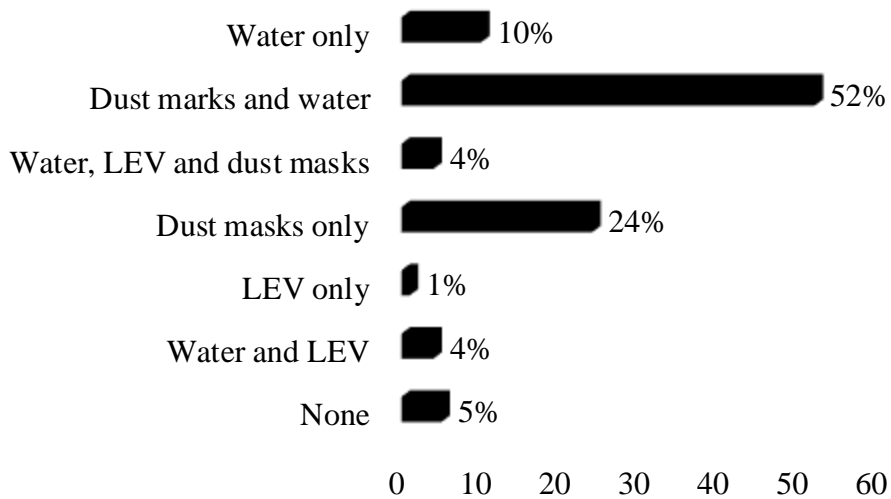


Figure 4.5: Dust Controls Used on Sites

According to 69% of respondents, the dust controls that were used on sites were not adequate to protect the workers from inhaling dust and to prevent symptoms of respirable diseases. Most of the respondents were aware of the dust as a hazard as 73% of them wore dust masks to protect themselves from respirable diseases as shown in Figure 4.6.

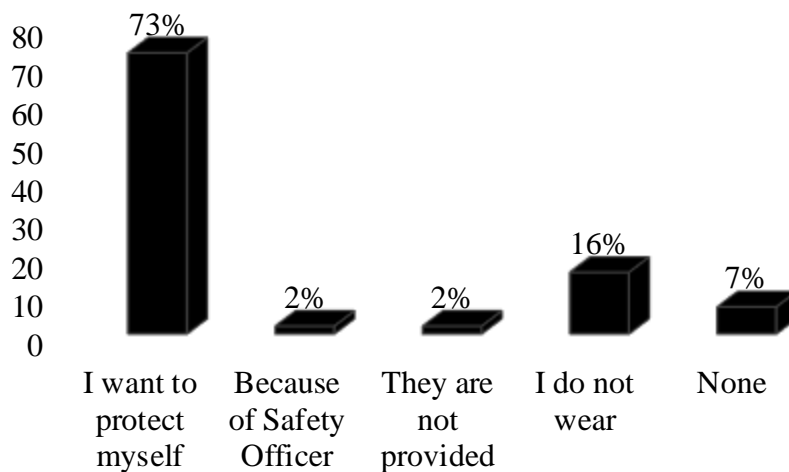


Figure 4.6: Reasons for Wearing Dust Masks

4.4.7 Silica Dust Controls and Prevalence of Symptoms of Respirable

Diseases

The methods that were used to control dust on sites was crossed-tabulated with the prevalence of symptoms of respirable diseases. The dust control type and the type of dust masks had a statistical relation with the prevalence of respirable diseases as presented in Table 4.17. The ρ -values for dust control type (0.000) and type of dust masks (0.036) were less than 0.05 for significance. The Pearson Chi-Square was 45 and df was 18 for dust control type and was 22 and df was 12 for type of dust masks. Hence, H_{N5} was rejected. The controls used for silica dust reduction were related to prevalence of symptoms of respiratory diseases. However, there was no statistical relationship between frequency of wearing dust masks and the prevalence of symptoms of respirable diseases as the Chi-Square was 13, $df = 9$ and ρ -value of 0.127 which was greater than 0.05 for significance.

Table 4.17: Dust Controls in relation to Symptoms of Respirable Diseases

Characteristics	Freq (%)	Symptoms of Respirable diseases				ρ -value
		Coughing N(%)	Wheezing N(%)	Shortness of breath N(%)	None N(%)	
Dust Control Type						
Water only	4	8(80)	0(0)	2(20)	0(0)	0.000
Water & LEV	4	4(100)	0(0)	0(0)	0(0)	
LEV only	1	1(100)	0(0)	0(0)	0(0)	
Dust Masks only	24	7(29)	5(21)	8(33)	4(17)	
Water, LEV & Dust Masks	4	3(75)	1(25)	0(0)	0(0)	
Dust Masks & Water	52	24(46)	25(46)	0(0)	0(0)	
None	5	5(100)	0(0)	0(0)	0(0)	
Frequency of Wearing Dust Masks						
Always	35	11(32)	13(37)	6(17)	5(14)	0.127
Sometimes	14	9(64)	3(22)	0(0)	2(14)	
In dusty environment	26	16(61)	7(27)	2(8)	1(4)	
I don't wear	25	16(64)	7(28)	2(8)	0(0)	
Dust Mask Type						
Disposable Dust Masks	13	10(77)	1(8)	0(0)	2(15)	0.036
Industrial	8	7(87)	0(0)	0(0)	1(12)	
N95	1	1(100)	0(0)	0(0)	0(0)	
Covid-19 Face Masks	53	18(34)	22(42)	8(15)	5(9)	
No Mask	25	16(64)	7(28)	2(8)	0(0)	

4.4.8 Controls Used on Sites for Chemical Irritants Exposure Reduction

The controls for chemical irritants used on sites which were; glove type, frequency of wearing gloves, frequency of hand washing, provision of gumboots and work suits, and frequency of application of hand cream (petroleum jelly) were cross-tabulated with the symptoms of skin diseases as shown in Table 4.18.

The ρ -values of frequency of wearing gloves (Pearson Chi-Square = 18, df = 8, $\rho = 0.019$), Provision of gumboots and Work suits (Pearson Chi-Square = 10, df = 4, $\rho = 0.034$), and nature of hands after work (Pearson Chi-Square = 16, df = 8, $\rho = 0.034$) were less than 0.05 hence there was a relationship. Therefore, H_{N6} was rejected. The controls used for silica dust and chemical irritants were related to prevalence of symptoms of skin diseases. Type of gloves, provision of washing facilities and frequency of hand cream application had no relationship with the prevalence of symptoms of skin diseases as their ρ -values were greater than 0.05 for significance. Respondents were aware of the chemical irritants as hazards as 56% of them wore gloves to protect themselves from skin diseases. Some respondents did not wear gloves for other reasons (30%) while 14% of the respondents indicated that management had not provided the gloves.

The three characteristics that were statistically significant namely frequency of wearing gloves, wearing of gumboots and work suits, and the nature of hands after work, were correlated for the type of relationship with the prevalence of the symptoms of the skin diseases. The type of relationship is shown in Table 4.19. There was a negative correlation between prevalence of symptoms of skin disease and, the frequency of wearing gloves (-0.347) and the wearing of gumboots and work suits (-0.262). The negative relationship means that as one variable increases, the other one reduces. The nature of hands after work has a positive relationship (0.237). The positive relationship means that as one variable increases the other one increases.

Table 4.18: Chemical Irritant Controls in relation to Symptoms of Skin Diseases

Characteristics	Freq (%)	Symptoms of Skin diseases				p-value	
		Itchy Hands N(%)	Scaly Hands N(%)	Vesicles on Hands N(%)	Red bumps N(%)	None N(%)	
Type of Gloves							
Disposable	4	0(0)	2(50)	0(0)	0(0)	2(50)	0.245
PVC	19	1(5)	5(26)	3(16)	2(11)	8(42)	
Cotton latex coated	29	5(17)	9(31)	1(3)	8(28)	6(21)	
Leather	6	0(0)	2(33)	1(17)	2(33)	1(17)	
No gloves	42	4(10)	21(50)	6(14)	6(14)	5(12)	
Frequency of Wearing Gloves							
Always	56	1(7)	1(7)	2(14)	2(14)	8(58)	0.019
Sometimes	14	5(11)	17(38)	3(7)	10(22)	10(22)	
I don't wear	30	4(10)	21(50)	6(15)	6(15)	4(10)	
Provision of Gumboots & Worksuits							
Yes	76	4(5)	29(38)	8(11)	15(20)	20(26)	0.034
No	24	24	6(25)	3(13)	3(13)	2(8)	
Adequacy of Washing Facilities							
Yes	89	9(10)	34(38)	9(10)	15(17)	22(25)	0.402
No	11	1(9)	5(46)	2(18)	3(27)	0(0)	
Frequency of Hand Washing							
Once at work	29	2(7)	15(51)	5(17)	5(17)	2(17)	0.435
Once at home	2	0(0)	1(50)	0(0)	1(50)	0(0)	
Sometimes at work	1	0(0)	1(100)	0(0)	0(0)	0(0)	
Several Times at work	68	6(7)	35(43)	8(10)	15(18)	18(22)	
Frequency Hand Cream							
Once per day	82	2(7)	15(51)	5(17)	5(17)	2(17)	0.336
Once per week	1	0(0)	0(0)	0(0)	0(0)	1(100)	
Once in a while	3	0(0)	1(33)	1(33)	1(34)	0(0)	
Not used before	14	4(29)	3(21)	2(14)	2(14)	3(22)	
Nature of Hands after work							
Very dirty	89	9(10)	39(43)	9(10)	16(18)	16(18)	0.034
A bit dirty	9	0(0)	0(0)	2(22)	2(22)	5(56)	
Not dirty	2	1(50)	0(0)	0(0)	0(0)	1(50)	

Table 4.19: Correlation between Prevalence of Symptoms of Skin Diseases and Controls

		Nature of hands after work	Wearing of gumboots and worksuits	Frequency of wearing gloves
Prevalence of the symptoms of the skin diseases	Pearson Correlation	0.237	-0.262	-0.347
	Sig. (2-tailed)	0.018	0.009	0.000
	N	100	100	100

4.5 Observation and Photographs Results

The data from observations were analysed using constant comparative method where the common themes were selected from what was observed in terms of dust and chemical irritant exposures, controls used to reduce exposures, the symptoms of skin diseases and the working environment. The photos were taken on both road and building projects to validate findings of what was observed.

4.5.1 Dust Exposures on Sites

Dust was observed from damping of gravel and stone base materials, excavations, loading of spoil and cutting concrete in the road project. Dust was produced from the process of batching, drilling, sanding and demolitions in the building project.

I. Dust Exposures on the Road Project

The photo in Figure 4.7 shows the tipper truck offloading gravel on the road project. Dust was seen escaping in the open air. Road workers, passers-by pedestrians, cyclist and traffic were exposed to the dust, thereby posing a health risk to the exposed. There was no dust control observed during this activities, therefore the road workers, passers-by pedestrians, cyclist and traffic were exposed to the same amount of dust that was emanating from the offloading of the gravel.



Figure 4.7: Picture showing dust exposure during offloading of gravel

The photo in Figure 4.8 depicts the excavator loading the spoil into the tipper truck during road construction. The excavator was loading a tipper truck with spoil to transport it to the dumping site. Road workers and road users were exposed to the dust in the process hence posing a health hazard to them. The dust exposure in Figure 3 extended to the nearby truck business premises.



Figure 4.8: Picture depicting dust exposure during loading of spoil

Grinding concrete was observed as one of the activities that exposed workers to dust in the road project as shown in Figure 4.9. The worker was seen performing dry cutting which produced dust. The worker and nearby workers were exposed to the dust being produced. Moreover, the worker was not in proper PPE except for the reflector vest. The worker was performing dry grinding during concrete drain shaping and the dust was seen during the activity in Figure 4. The worker was seen without the recommended PPE such as dust mask, gloves, work suits, safety boots and hardhat.

II. Dust Exposures on the Building Project

Workers were observed loading quarry dust for batching and dust was being produced as shown in Figure 4.10. One worker had no mask while the other one was wearing a disposable mask. The workers were loading quarry dust for batching. The dust was seen as a result of loading. The worker who was loading was seen without a dust mask and the other one was wearing a Covid-19 facemask. The workers were likely to be exposed to dust which is harmful to their health.



Figure 4.9: Picture showing dust exposure during dry concrete grinding



Figure 4.10: Picture showing workers loading quarry dust for batching

There was exposure to dust which was observed during sweeping as part of housekeeping as presented in Figures 4.11. Dust was coming from the concrete and mortar remains as they were being swept during housekeeping. To reduce dust exposure, other controls like water was supposed to be used together with the recommended PPE especially dust masks. The worker was seen in the PPE but had a facemask instead of the recommended dust mask. The Covid-19 face mask was inadequate in reducing the exposure to dust as it was specifically made for Covid-19 prevention.



Figure 4.11: Picture showing dust exposure during sweeping

Other dust producing activities which were observed to expose workers to dust were; opening of cement bags during mortar making and demolition. There was cement dust escaping into open air as the worker in Figure 4.12 was opening a bag of cement during the manual mixing for plaster and mortar at a building site. The worker was noticed wearing a black cloth face mask which was recommended for Covid-19 prevention. Face masks are not recommended for silica dust reduction as its particles are so tiny that they penetrate surgical and cloth face masks designed for Covid-19 prevention. Workers were exposure to dust which was being produced from hammering the walls of the building and also during loading of materials from demolition as depicted in Figure 4.13.



Figure 4.12: Picture showing cement dust exposure during dry mixing



Figure 4.13: Picture showing dust exposure during demolition and loading of rubble

One worker was breaking the wall using a hammer and the other one was manually loading the rubble. Dust was seen being produced from both activities especially when manually loading the rubble. The workers were wearing Covid-19 recommended face masks.

4.5.2 Chemical Irritants Exposures on Sites

The results from observation revealed that workers were exposed to chemical irritants both on the road and building projects. Some workers were observed to have direct contact with chemical irritants as they had no gloves and gumboots to reduce exposure. Also, the workers were seen to work full-work shift of eight hours or more in some cases.

I. Chemical Irritants Exposures on the Road Project

The exposure to chemical irritants, on the road project were mainly during concrete drainage and walkway construction, priming and tack coat application. Workers were exposed to wet concrete. The worker in Figure 4.14 was exposed directly to wet concrete as he was working without gloves. In the course of priming and tack coat application, workers were exposed to bitumen in the primer and tack coat as shown in Figure 4.15. The worker's hands were directly exposed as he was not wearing gloves while working.



Figure 4.14: Picture showing exposure to wet concrete on the road project



Figure 4.15: Picture presenting exposure to bitumen on the road project

II. Chemical Irritants Exposures on the Building Project

The activities which exposed workers to chemical irritants on the building projects were; working with wet concrete, building plastering and painting. Figure 4.16 shows the worker being exposed to wet concrete on both hands and feet as he had no required PPE. During building, there was exposure to cement in the mortar because of torn and wrong gloves for the activity as shown in Figure 4.17.



Figure 4.16: Picture showing exposure to wet concrete on the building project



Figure 4.17: Picture presenting exposure to wet mortarduring building

Plastering exposed workers to wet cement. The exposure was direct to the skin as some workers did not wear gloves as presented in Figure 4.18. In addition, workers were exposed to paint as evidenced in Figure 4.19. The worker's hands and work suit had splashes of paint. The workers were observed working without gloves.



Figure 4.18: Picture showing exposure to wet mortar during plastering

4.5.3 Symptoms of Skin Diseases

The symptoms of skin diseases which were observed on both sites were fissures on hands, scaling of hands, vesicles on hands and red bumps on the hands.

I. Fissures on hands

According to Yates (2005), skin fissures are splits in the skin and may bleed. Fissures on hands was observed in the workers as shown in Figure 4.20.

II. Scaling of hands

Scaling of hands was observed as the peeling of the skin as shown in Figures 4.21 and 4.22. It was the most common observed skin symptom on both road and building.



Figure 4.19: Picture showing exposure to paint during painting



Figure 4.20: Picture showing hands with fissure



Figure 4.21: Picture showing dry scaly hands



Figure 4.22: Picture showing wet scaly and hands

III. Vesicles on hands

Vesicles are small fluid-filled blisters. Vesicles become hard with time as in Figure 4.23.



Figure 4.23: Picture showing vesicles on hands

IV. Red Bumps on hands

The red bumps were not common because when they appeared on the worker's hands, they could burst with time and become sores as shown in Figures 4.24.



Figure 4.24: Picture showing red bumps

4.5.4 Controls Used on Sites for dust Exposure Reduction

The workers were seen on cutting asphalt road using a cutter that had water and the use of face masks to control exposure to dust as shown in Figure 4.25. Workers were cutting asphalt road using concrete cutter. The concrete cutter had a water tank mounted on its back. As the concrete cutter was cutting asphalt, water was dripping on the cutting blade suppressing the dust which was being produced. Therefore, less dust was observed escaping in to the open air during the cutting activity.



Figure 4.25: Picture showing the use of cutter with water on the road project

Some parts of the road project, workers were using water to reduce dust emissions during base construction as presented in Figure 4.26. The worker was seen removing some wetted gravel back on the road base during base processing. The worker had sprayed some water to suppress dust thereby reducing dust exposure for himself and the traffic. Despite the water suppression control, the worker was not wearing the recommended full PPE for dust and chemical exposure reduction.



Figure 4.26: Picture showing dust control using water on the road project

In both road and building projects, most of the workers were wearing face masks which were recommended for Covid-19 prevention. The face masks were surgical masks and cloth face masks as shown in Figure 4.27. The clearly seen in a surgical face mask yet he was working on a dusty activity. The worker was loading quarry dust in wheel barrow for batching. The loading activity was producing dust as can be seen in the picture.



Figure 4.27: Picture showing a worker wearing a face mask while working

The worker in Figure 4.28 was seen wearing a recommended dust mask. He was seen opening the bag of cement to load in the concrete mixer to make concrete. Since the dust mask was one of recommended RPE it meant that it was able to protect the work from inhaling all the dust around the breathing zone. Very few used dust masks like the worker.



Figure 4.28: Picture showing a worker wearing a dust mask while working

4.5.5 Controls Used on Sites for Chemical Irritants Exposure Reduction

The observed controls for chemical irritants were gloves, work suits, gumboots and safety shoes. The types of gloves which were used are presented in Figures 4.29 and 4.30.



Figure 4.29: Picture showing the use of cotton-PVC gloves



Figure 4.30: Picture showing the use of PVC gloves

Some workers were provided with work suits and gumboots to control exposure to chemicals. Three of the workers in Figure 4.31 were given gumboots while one was not and he was not in a full work suit.

4.5.6 Provision of Adequate PPE

It was observed that most of the workers were not provided with the adequate PPE according to their work activities. The worker in Figure 4.32 was not provided with the gumboots, work suit and gloves to control exposure to chemical irritants. Some workers were given safety boots yet worked in wet concrete as depicted in Figure 4.33. It was observed that they were few gumboots that were provided, and this led to workers exchanging gumboots depending on where they were working. The worker in Figure 4.34 was working without adequate PPE (work suit, gloves, safety boots, hardhat, dust mask). The worker was seen wearing a cloth mask and a reflector vest only.



Figure 4.31: Picture showing some of the workers in gumboots



Figure 4.32: Picture showing exposure to wet concrete without PPE on a building project



Figure 4.33: Picture showing wrong PPE for working with wet concrete



Figure 4.34: Picture showing a worker without adequate PPE

4.6 Summary

Chapter four gave the results from the air sampling in terms of silica dust concentrations from the air sampling which were high comparable to OSHA PEL. All the findings and the interpretation of the results from both the questionnaire survey and the observations were also presented in addressing the objectives of the research.

CHAPTER 5: DISCUSSION OF RESULTS

5.1 Introduction

The results from the silica sampling, questionnaire survey and observation and photographs were presented in the previous chapter. This chapter presents the discussion of the results and how the objectives, research questions and hypotheses were answered. The questionnaire results are based on the respondents. Therefore, the percentages are the representation of responses from respondents.

5.2 Silica Exposure Levels in Relation to Occupational Safety Health Administration Permissible Exposure Limit (0.05mg/m³)

There was a statistically significant result using One-Sample test that revealed that silica dust exposure levels were above OSHA PEL of 0.05mg/m³. This was because the df was 14, at 95% confidence (0.05), the CV was 1.761 in the Student's t distribution table ($t > CV$), $p < 0.05$ at 95% confidence interval of the difference of lower (1.069) and upper (1.63) did not cross the zero hence significant. Therefore, the null hypothesis that the levels of silica dust construction specialised personnel were exposed to in Zambia were below OSHA PEL (0.05mg/m³) was rejected. This means that the silica dust levels construction specialised personnel were exposed to were above OSHA PEL. Levels above OSHA PEL are considered high exposures and can lead to respirable diseases. This finding of high silica dust levels above 0.05mg/m³ were similar to discoveries by Normahammadi et al. (2016) and Flanagan et al. (2003).

The results from the RCS sampling showed that the overall GM was 0.04mg/m³ which was 20% less than OSHA PEL of 0.05mg/m³ respectively. The GM for RCS (0.04mg/m³) was comparable to Li et al. (2019)'s findings of 0.03mg/m³. This was despite Li et al. (2019) having 723 personal air samples while this research had only 15 samples. Nevertheless, the GM found in this study was less than 0.11mg/m³ which was found in the study by Flanagan et al. (2003). The difference in the two studies may have been that full-shift was used in this study while Flanagan et al. (2003) used half shift. Moreover, this study focused on specialised workers or job title while in the study by Flanagan et al. (2003), the focus was on the activity. Also

the GM findings of the present research was different from Lumens and Spee (2001) whose GM was 1.1mg/m³.

The AM exposure level (0.228mg/m³) was 78% more than OSHA PEL of 0.05mg/m³. The AM concentration (0.228mg/m³) for this research was more than 0.190 mg/m³ by Normahammadi et al. (2016). This is despite the GM level of 0.04mg/m³ in this study being lower than the GM of 0.132 mg/m³ by Normahammadi et al. (2016). The mean RCS exposure level was 0.119mg/m³ which was 58% above and 2.4 times the OSHA PEL. The highest exposure was 97% above and 32 times OSHA PEL.

The silica content in this research ranged from 1.5 to 18% which are lower than Lumen and Spee (2001) who found over 40% and Flanagan et al. (2003)'s study whose range was from 2.2 to 21%. However, it is higher than 15% which was found by Li et al. (2019). The silica content in the current research gives an indication of high silica dust exposures.

The highest individual concentrations for RCS was 1.58mg/m³ which is 96% higher than OSHA PEL (0.05 mg/m³). On the individual exposures in the current study, 40% were above the OSHA PEL while in Normahammadi et al. (2016)'s, study 80% of the workers were exposed to levels more than OELs. The difference in the findings could have being that Normahammadi et al. (2016) sampled the demolition workers only whereas in this study, sampled workers were bricklayers, carpenters, painters, demolition workers, tilers and their labourers. The carpenters and their labourers had the highest GM (0.1582mg/m³) for RCS compared to bricklayers (0.007mg/m³), demolition workers (0.029mg/m³), tilers (0.010mg/m³) and painters (0.026mg/m³). This is unlike the finding by Lumen and Spee (2001), Normahammadi et al. (2016) and Kirkeskov et al. (2016) who suggested that demolition workers are more exposed to silica dust. Moreover, the finding is different from Rappaport et al, (2003) who reported painters to be more exposed and Flanagan et al. (2003) who found that masons and their labourers were more exposed to silica dust. In the case of Rappaport et al. (2003), painters performed abrasive blasting that is why they had higher exposures. The reason for the difference in the current results would have been that carpenters were drilling and cutting concrete

blocks indoors while the sampled demolition worker was working outdoor, during the rainy season which may have reduced the dust as shown in Figure 4.13.

Despite the all the skilled recording different silica exposure levels and carpenters recording highest exposure level, there was no statistical significance between job title and RCS and RD exposure levels. This means that the exposure levels do not depend on the job title. However, the findings of different exposure levels in the job titles during air sampling would mean that the exposure levels depend on the activity being carried out as suggested by Flanagan et al. (2003). This can be seen in the results of carpenters recording highest exposure levels compared to other job titles. This was because carpenters were drilling and cutting concrete indoors, for their activities on the building project as suggested by Eli et al. (2019) that such activities produce high silica exposure levels. The important thing is that the findings showed that the sampled skilled were exposed to high silica levels which were above OSHA PEL and these skilled may perform similar activities that produce high silica dust.

The GM and AM for RD exposure levels were $0.779\text{mg}/\text{m}^3$ and $3.198\text{mg}/\text{m}^3$ which were 84% and 36% less than OSHAL PEL of $5\text{mg}/\text{m}^3$ respectively. Similarly, the GM results were 55% less than the recommended legal dust limit in Zambia of $1.74\text{mg}/\text{m}^3$ which was used in the study by Nsunge (2019) as a reference because Zambia has no permissible exposure limits for RCS dust and RD. The results were comparable to findings by Kirkeskov et al. (2016) who found that the concentrations for RD were below the exposure limit of $5\text{mg}/\text{m}^3$. In the study by Kirkeskov et al. (2016), the GM for demolition workers was $1.06\text{mg}/\text{m}^3$ and GM for carpenters was $0.27\text{mg}/\text{m}^3$. The similarity in the two findings would have been that full day shifts were used in both studies. Nevertheless, the finding of $0.779\text{mg}/\text{m}^3$ is different from Lumens and Spee (2001)'s discovery whose GM was $5.2\text{mg}/\text{m}^3$ which was above the limit value. The use of less than full day shift would have been the reason for the higher levels of RD in Lumens and Spee (2001)'s study. The mean RD exposure level for the current research was the same as the AM result of $3.198\text{mg}/\text{m}^3$ which was 36% less than the OSHA PEL and was 46% more than the Zambian exposure limit.

The highest individual concentrations for respirable dust was $23.19\text{mg}/\text{m}^3$ which was 78% higher than OSHA PEL of $5\text{ mg}/\text{m}^3$. The RD individual exposure levels, 13% were above the OSHA PEL. This finding is different from Kirkeskov et al. (2016) as in their case nine percent, that is one out of 11 measurements of the individual measurements was above the OEL for demolition workers. For the present study, the highest exposure for RD was 78% above and five times OSHA PEL of $5\text{ mg}/\text{m}^3$. Furthermore, this was agreeable with the One-Sample test which showed statistically significant that RD exposure levels were above OSHA PEL of $5\text{mg}/\text{m}^3$ as the CV (1.761) was less than t (42.560), $p < 0.05$ and at 95% confidence interval of the difference of lower (-4.062) and upper (-3.672) did not cross the zero hence showing significance.

The results from the questionnaire survey showed that all the respondents experienced dust exposures of which 86% experienced high exposures. This agrees with the 40% and 13% individual exposures for RCS and RD which were above OSHA PELs respectively. In addition, it was supported by the mean for RCS of $0.119\text{mg}/\text{m}^3$ which was 58% more than OSHA PEL or 2.4 times OSHA PEL. In the same way, the results from observations support the findings showing exposure to dust when offloading gravel, loading of spoil, dry grinding, loading of quarry dust for batching, when sweeping, dry mixing of cement and quarry dust and demolition and loading of rubble. These reveal the evidence of part of dust that was sampled for silica dust and respirable dust sampling and what was being referred to by respondents when answering the questionnaires.

The reason for high difference in percentages of the silica dust sampling exposure levels (mean RCS, 58%) and questionnaire survey (high levels of exposure, 86%) would have been that sampling for respirable and silica dust were only done on the building project while the questionnaire survey was conducted on both the road and building projects. The respirable and silica dust sampling was only done on the building project because of the heavy rains which meant there were no dust exposures on the road project. The respirable and silica sampling media was hired from NIOH South Africa and took long to be received in Zambia. The silica dust sampling media was hired from NIOH South Africa because there was no institution that had such equipment in Zambia during the research period. By the time the

sampling media was received, the rains were at peak and there were no longer dust exposures on the road project. Besides, the road works were suspended due to heavy rains.

5.3 Dust Levels in Relation to Prevalence of Symptoms of Respiratory Diseases

The prevalence of symptoms of respiratory diseases (coughing, wheezing and shortness of breath) according to respondents was at 92%. Coughing was the most prevalent at 52% followed by wheezing at 30% and shortness of breath at 10%. The results of prevalence of symptoms such as wheezing and shortness of breath in this study were less than what was found in Nsunge (2019) where wheezing was 45% and shortness of breath was 39%. Nsunge (2019) found that the most prevalent symptom of respiratory diseases was nose irritation (59%) while in this study the most prevalent was coughing (52%). This was despite the questionnaires being used in both studies. The questionnaire in this study was formulated after literature review while Nsunge (2019) used the modified ATRQ. The reason for the difference in the prevalence of the symptoms of respirable diseases in the two studies would have been that Nsunge (2019) sampled the road construction workers while in the current study, building and road construction workers were sampled.

Nevertheless, there was no statistical relationship between the dust levels and the prevalence of symptoms of respirable diseases as p-value (0.117) was greater than 0.05 for significance. Hence the second null hypothesis that stated that dust levels were not related to prevalence of symptoms of respiratory diseases was accepted. This outcome was regardless of findings of high levels of dust exposures from silica dust sampling, questionnaires and observation and high prevalence of respiratory diseases. However, they contradict with the findings by Nsunge (2019) and Hafiz and Abdelridha, (2012) who found that there is a relationship between the dust exposures and symptoms of respiratory diseases. The reason for no statistical relationship in this study would have been that the respiratory diseases such as silicosis and its symptoms take long to manifest and they depend on the quantities of silica dust inhaled. Since this research was a cross-sectional one, the symptoms would not have been established right there and then. Moreover, the method that was used in this study (questionnaire survey) would have affected the relationship unlike

the use of full respiratory clinical examinations which give real diagnosis of the symptoms of respiratory diseases. Also, the longitudinal study may have given a different outcome.

5.4 Levels and Period of Exposure to Chemical Irritants in Relation to Symptoms of Skin Diseases

The levels of exposure to chemical irritants were high (85%) and the high exposure levels were associated to having dirty hands after work (89%). This was as a result of workers not using any or suitable PPE in spite of 56% of the questionnaire respondents wearing gloves to protect themselves. However, the workers wore unsuitable gloves for the job as was observed. The findings were verified from the observation results on exposure to chemical irritants (exposure to wet concrete), (exposure to bitumen), (exposure to wet cement in mortar). The figures reveal the exposure levels as the hands are covered in dirty resulting in skin irritation. The high exposure levels, from the results could have led to the 78% prevalence of symptoms of skin diseases. The findings also showed that the most common symptoms were scaly hands (39%) followed by red bumps (18%). The scaly hands symptom was the most common because of the exposure to wet cement or concrete which was the most observed exposure. Furthermore, the findings on scaly hands as most common symptom of the skin diseases were agreeable with the findings in the observation results as presented. Other skin symptoms were hands with fissures, vesicles on hands and red bumps on hands.

The relationship between the levels of exposure to chemical irritants and the symptoms of skin diseases was tested for significance. There was a statistical significance since the p -value was 0.006 which was less than 0.05. Therefore, the null hypothesis which stated that the levels of exposure to chemical irritants for construction specialised personnel in Zambia were not related to prevalence of symptoms of skin diseases was rejected. The findings of high exposure levels to chemical irritants and the workers not wearing suitable PPE are similar to findings of Mashqoor et al. (2017), Bedoya-Marrugo et al. (2017), Bhuiyan et al. (2015) and Shah and Tiwari (2010), who associated the prevalence of symptoms of skin diseases to not wearing the PPE. The argument was that not wearing PPE resulted in high exposures and eventually the occurrence of symptoms of skin diseases. Scaly hands

or fingers was more associated to higher levels of exposure. Scaling of the skin can affect quality of life of workers and affect their ability to perform their work effectively. The results showed that all the skilled workers who participated in the study were exposed to chemical irritants that were likely to cause symptoms of skin diseases.

There was no relationship between levels of exposure to chemical irritants and type of construction. This would have been because skilled workers performed similar works and that the chemical irritants are similar in both road and building projects. One similar chemical irritant is working with wet cement. On the job title, the comparison of means gave an indication that demolition workers and tilers were likely to be more exposed as their means were high. Nevertheless, the results of cross tabulation showed that bricklayers are more exposed to chemical irritants compared to the other skills. Despite no statistical relationship between levels of exposure and job title, there was a statistical relationship between job title and the prevalence of symptoms of skin diseases. Bricklayers were more likely to develop all the symptoms of skin diseases (94%) compared to other job titles. This finding is similar to Saji et al (2018). On the contrary, Esmail and Sakwari (2021), found that carpenters were more likely to develop skin diseases. The reason for the difference may have been that bricklayers were handling wet works that are associated with high exposure to chemical irritants. On the common skin symptom, painters experienced scaly hands more than other job titles (67%).

The findings showed that 62% of respondents were exposed between three and eight hours in a day while 32% were exposed for more than 8 hours. This gave an indication that many workers worked a full shift of eight hours which is legal working hours according to Zambian labour laws. The 32% who worked for more than the full shift, worked overtime because both the road and building projects were behind their project schedules. Moreover, workers hoped to work overtime to make more money as they were on daily or hourly rates. This meant that the more hours they worked the more money they made for their wages. The results indicated that the workers who worked for more than three hours (62% and 32%) experienced symptoms of the skin diseases as the prevalence of the skin diseases was at 78%. Of all the workers who experienced scaly hands as a symptom of skin disease, which

was the most common, 49% were exposed between three and eight hours. The relationship between period of exposure to chemical irritants and prevalence of symptoms of skin diseases was tested and it was statistically significant as p-value of 0.023 was less than p-value of 0.05 for significance. Hence, the null hypothesis that the period of exposure to chemical irritants for construction specialised personnel in Zambia was not related to prevalence of symptoms of skin diseases was rejected.

Therefore, the longer the period of exposure the more likelihood of occurrence of the symptoms of skin diseases. This is similar to finding by Esmail and Sakwari (2021), Saji et al. (2018), Bedoya-Marrxugo et al. (2017), Bhuiyan et al. (2015) and Shah and Tiwari (2010) who found that the period of exposure to chemical irritants is associated to the occurrence of skin diseases. In the case of Esmail and Sakwari (2021) and Saji et al. (2018), the period of exposure was considered in years while in this study, hours were used.

5.5 Controls Used on Sites for Silica Dust in Relation to Symptoms of Respiratory Diseases

The most common dust control used on sites was a combination of water and dust masks which was at 52% followed by dust masks only at 24%. The control by use of water only was 10% and no control was five percent. The combinations of water, LEV and dust masks, and water and LEV were both at four percent. There were cases of the use of LEV only which was at one percent. These findings revealed that the dust controls used on sites were not adequate as the combination of controls namely LEV, water and dust masks was at four percent which was low. In fact, several studies have shown that the use of one type of control does not adequately reduce RCS exposure levels below the permissible limits (Tente et al., 2022). These questionnaire results were supported by the findings in what was observed. There was a consensus among respondents as 69% of them agreed that the controls used on sites were not adequate to reduce dust exposure to protect the workers. This finding was in line with the prevalence of symptoms of respirable diseases which was at 92%. If the controls were adequate, the prevalence of respirable diseases was expected to be very low.

In addition, there was a statistically significant relation between prevalence of respirable diseases and dust control type, and the type of dust masks as their p -values were less than 0.05. Therefore, the hypothesis which stated that the controls used for silica dust were not related to prevalence of symptoms of respiratory diseases, was rejected. From the findings it can be deduced that the less adequate the controls, the more prevalent the symptoms of respirable diseases. Moreover, the type of controls was more associated with coughing which was found to be the most common symptom of respirable diseases. In spite of the combination of water and dust masks being commonly used as control type, it had its challenges.

According to the respondents, the use of water as dust control in the building project had its own challenges of messing the place and making an activity a bit difficult to perform similar to findings by Carlo et al. (2010). The challenge of using water made workers to avoid it in order to ease their work activity. On the road project, the challenge of the use of water for dust control or suppression was that workers had to keep spraying every after an hour or more depending on the weather conditions. This was a serious challenge as spraying water was not done as often because they preferred to use water for road works. The example of road works that required the use of water was base processing. Therefore, workers preferred to use water for base processing rather than dust control in order to meet the deadlines as the project was behind schedule. In addition, water was fetched far from the road sites and transporting it in heavy traffic of Lusaka city, made water erratic on sites. This contributed to inadequacy dust controls on the road sites on the road project.

The use of dust masks was second most used at 24%. However, the type of dust mask was important in relation to the symptoms of respiratory diseases as there was a statistically significant relation. The most common type of masks used were Covid-19 face masks which was at 53%. This was the case because during data collection Covid-19 was prevalent and as a preventive measure, all workers were mandated to wear the Covid-19 face mask. Other masks that seem to be recommended for silica dust exposure reduction such as disposable dust masks, industrial dust masks and N95 were rarely used on sites. This is evidenced in what was observed on the building project where only one worker was spotted wearing an N95 dust mask as shown in Figure 4.28.

The statistical significance relationship between the type of dust masks and the prevalence of symptoms of respiratory diseases means that when the type of dust mask is adequate, it reduces exposure to some extent thereby lowering the prevalence rate of symptoms of respiratory as suggested by Ahmed and Abdullah (2012). However, if the inadequate dust mask is used, it does not reduce exposure to silica dust. The findings of the suitability and adequacy of the dust mask (RPE) is similar to some researchers who advised from their findings that to reduce exposure to silica dust, a suitable and well fitted RPE is required (Ahmed and Abdullah; 2012 Flanagan et al., 2003). However, from literature review, it can be concluded that despite the use of RPE as a control to reduce exposure to silica dust, it does not reduce silica exposure levels to below PEL (Tente et al., 2022). This is the reason why it is recommended that the use of RPE and PPE should be the last one in the hierarchy of controls as advised by Flanagan et al. (2003).

Additionally, there was no statistical relationship between frequency of wearing dust masks and the prevalence of symptoms of respiratory diseases as the p -value was 0.127 which was greater than 0.05 for significance. This meant that regardless of the frequency of wearing inadequate mask, even if it was used always (35%), it could not reduce exposure to silica dust. This finding is similar to Ahmed and Abdullah (2012), who found that the use of appropriate respiratory protection reduced the prevalence of symptoms. The Covid-19 face mask, which was commonly used in this study was not adequate since it is not recommended for silica dust reduction. Covid-19 face masks were always used because they were mandatory to be worn by all workers during Covid-19 pandemic as a directive from Ministry of Health. This can be verified in figures showing worker wearing Covid-19 face masks. Therefore, despite it being worn always, it did not reduce the prevalence of symptoms of respiratory diseases associated to dust exposures because the prevalence of respiratory diseases was at 92%.

5.6 Controls Used on Sites for Chemical Irritants in Relation to Symptoms of Skin Diseases

The common used controls for chemical irritants were gloves, gumboots, work suits, washing of hands and application of hand cream, the common cream was petroleum jelly. There was no relationship between the type of gloves and the prevalence to

symptoms of skin diseases as the ρ -value (0.245) was greater than 0.05 for significance. The reason for no relationship was that despite the use of gloves on both sites as control, 42% of respondents did not wear any gloves either because of other reasons (30%) or the gloves were not provided by management (14%). Some of the reasons for not wearing gloves were that the provided gloves were not suitable for the job task and so they could not offer the protection as shown in Figure 4.29. The none provision of gloves and provision of unsuitable gloves as reasons for not wearing gloves by some respondents, can be supported by the finding that 56% of respondents were willing to wear gloves to protect themselves if they were provided. This gave an indication that respondents were aware of the chemical irritant hazards as they wanted to protect themselves.

The ρ -values of frequency of wearing gloves (0.019), provision of gumboots and work suits (0.034) and nature of hands after work (0.034) were less than 0.05 hence there was a statistical relationship. Moreover, there was a negative correlation between prevalence of symptoms of skin disease, the frequency of wearing gloves (-0.347) and the wearing of gumboots and work suits (-0.363) respectively. The negative relationship means that as one variable increases, the other one reduces and the opposite is true. This meant that the more frequent, the suitable and well fitted gloves were worn, the less prevalence the symptoms of skin diseases. Also the more quality and suitable gumboots and work suits were worn, the less the prevalence of symptoms of skin diseases. In the current study, 42% of respondents did not have gloves and 56% wore gloves always. The observation results support the 42% respondents who had no gloves. This meant that the workers were more exposed to chemical irritants and eventually develop symptoms of skin diseases. Furthermore, despite the 56% always wearing gloves during work, some of them had poor quality unsuitable and/or torn gloves. Therefore, the implication of the negative correlation results is that when the quality and suitable PPE (gloves, gumboots and work suits) is worn, the exposure to chemical irritants is reduced and eventually less prevalence of symptoms of skin diseases. This is similar to recommendations by Tente et al. (2022) and Timmerman (2017) that wearing of quality, skilled approved and well fitted PPE (gloves) reduces exposure of workers' skin to chemical irritants.

On the other hand, the nature of hands after work had a positive correlation with the prevalence of symptoms of skin diseases (0.237). The positive relationship means that as one variable increases the other one increases as well. Having very dirty hands after work was common among respondents (89%). From the positive relationship between nature of hands after work and prevalence of symptoms of skin diseases, it can be deduced that the dirtier the hands are after work, the more prevalent the symptoms of skin diseases similar to Tente et al. (2022) and Timmerman (2017)'s findings. Likewise, the findings agree with Mashqoor et al. (2017), Bedoya-Marrugo et al. (2017), Bhuiyan et al. (2015), Shahand Tiwari (2010) who argued that the levels of exposure to chemical irritants were related to prevalent of symptoms of skin diseases. This is because dirtier hands after work meant that workers were exposed to higher levels of chemical irritants. However, provision of washing facilities and frequency of hand cream application had no relationship with the prevalence of symptoms of skin diseases as their p -values were greater than 0.05 for significance. This was despite 89% of respondents agreeing that there was adequate provision of washing facilities and 82% of respondents using petroleum jelly as hand cream per day.

5.7 Summary of the Findings

The findings showed that the levels of silica dust exposure levels the construction personnel were exposed to were above OSHA PEL of $0.05\text{mg}/\text{m}^3$. This was from the individual RCS results and One-Sample test that was significant. Therefore, the silica dust levels construction specialised personnel were exposed to were above OSHA PEL. There was no statistical relationship between dust levels and to prevalence of symptoms of respirable diseases. This was despite prevalence of symptoms of respirable diseases being high (92%) and coughing was the most prevalent. The levels of exposure to chemical irritants were found to be related to prevalence of symptoms of skin diseases. In addition, the exposure levels to chemical irritants were high and were associated to dirty hands and not wearing PPE or unsuitable PPE. There was also a relationship between the controls used for silica dust. The less adequate the controls, the more prevalent the symptoms of respirable diseases. Lastly, there was a relation between prevalence of respiratory diseases and dust control type, and the type of dust masks.

The findings pointed to the fact that specialised workers in the construction industry in Zambia were affected by the following important health concerns;

- i) The workers were exposed to high silica dust levels which were more than 0.05mg/m³ and could cause symptoms of respiratory diseases.
- ii) The workers were exposed to high levels and long period of exposure to chemical irritants and led to symptoms of the skin diseases.
- iii) The prevalence of both the symptoms of respiratory diseases and skin diseases was high.
- iv) The controls that were used on sites for silica dust and chemical irritants reduction were inadequate.

The summary of the findings in relation to the objectives in as shown in Table 5.1.

Table 5.1: Summary of Findings in line with Objectives

Item	Objectives	Findings
1	To establish levels of silica dust construction specialised personnel were exposed to in relation to OSHA PEL (0.05mg/m ³).	Silica dust levels construction specialised personnel were exposed to were above OSHA PEL (0.05mg/m ³).
2	To assess the dust levels in relation to the prevalence of symptoms of respiratory diseases.	Dust levels were not related to the prevalence of symptoms of respiratory diseases.
3	To determine the levels and period of exposure to chemical irritants in relation to prevalence of symptoms of skin diseases for construction specialised personnel in Zambia.	Levels and period of exposure to chemical irritants were related to prevalence of symptoms of skin diseases for construction specialised personnel in Zambia.
4	To identify current existing controls for silica dust and chemical irritants in relation to prevalence of symptoms of respiratory and skin diseases.	Current existing controls for silica dust and chemical irritants were related to prevalence of symptoms of respiratory and skin diseases.
5	To develop an integrated preventive framework for specialised construction site personnel exposed to silica dust and chemical irritants.	An integrated preventive framework to mitigate exposures to silica dust and chemical irritants was developed based on findings and literature review.
6	To validate the developed integrated framework using construction stakeholders and experts.	The developed integrated framework was validated using construction stakeholders and experts.

The exposure levels to silica dust and chemical irritants were high and the inadequate site controls pose a health risk to the workers and the projects. Therefore, there is need to reduce exposure to silica dust and chemical irritants to prevent respiratory and skin diseases in order to protect the workers and safeguard the projects. Thus an integrated preventive framework is recommended to mitigate exposures to silica dust and chemical irritants.

Chapter 5 gave the discussion of the findings. The next chapter presents the development of an integrated framework which is as a recommendation to address the problems established in the findings. The development of the framework was informed by the findings and the literature that was reviewed on how to mitigate the exposures to silica dust and chemical irritants throughout the project and it was based on the framework for program evaluation (Centers for Disease Control and Prevention, 1999) as presented in section 2.5.

CHAPTER 6: PREVENTIVE FRAME WORK DEVELOPMENT

6.1 Introduction

The previous chapter gave the discussion of the results and brought out the need to reduce exposure to silica dust and chemical irritants to protect the workers from symptoms of respirable and skin diseases. The current chapter gives the development of a preventive framework that would be used in the construction industry in Zambia to reduce exposure to silica dust and chemical irritants. Moreover, this chapter addresses the fifth and main research objective in section 1.4 (v), which was to develop an integrated preventive framework for construction personnel exposed to silica dust and chemical irritants. Chapter six also gives the importance of the framework, how it will work and the validation process.

6.2 The Importance of the Framework

Construction dust is unavoidable and cannot be completely removed despite its devastating effects when inhaled depending on the duration and levels of exposures. Fortunately, construction dust especially silica dust can be reduced below the recommended (OSHA PEL of $0.05\text{mg}/\text{m}^3$) level that do not pose a health risk to workers. Therefore, the purpose of the framework is to help reduce exposures to silica dust and chemical irritants as a preventive measure of respiratory and skin diseases in the construction industry. Moreover, the framework would prevent and reduce the effects of symptoms of respirable and skin diseases on the workers and productivity on the construction projects. Overall the framework will help avoid incidences that are stressful, time consuming and costly to both workers and construction projects that are brought about by exposures to silica dust and chemical irritants hazards.

To adequately reduce exposure to silica dust and chemical irritants hazards and reduce the number of occupational deaths and illnesses which are brought out by such hazards, the framework which addresses/incorporates ways of reduction is recommended. The focus of the framework is to reduce the hazards and risks at every stage in order to significantly reduce exposure to silica dust and chemical irritants and eventually the risk of occurrence of symptoms of respirable and skin diseases. In addition, the framework addresses the following;

- i) Sustainable Development Goals number three of achieving good health and well-being by 2023 by way of reducing a number of deaths and illnesses caused by hazardous chemicals and air pollution and contamination.
- ii) Research problem – construction specialised personnel experience silica dust and chemical irritants hazards that lead to symptoms of respirable and skin diseases in Zambia.
- iii) Aim of the research-to establish an integrated preventive framework that can be used to reduce exposure to silica dust and chemical irritants for construction site personnel in Zambia.
- iv) Purpose of the research - to safeguard the lives of the specialised skilled personnel and prevent the effects on construction the projects through prevention of symptoms of respirable and skin diseases by ways of reducing exposures to silica dust and chemical irritants in Zambia.

The framework presents three main stages, namely: preliminary prevention; enforcement prevention; and execution prevention. It also shows relationships of the construction stakeholders who are involved in the construction project team that is: the client (developer); consultants (consulting engineers); government and its agencies; contractors and the subcontractors; suppliers; construction personnel; and the community. In addition to the traditional or most common project team, **health and safety practitioners** have been added to the project team in the framework.

6.3 How the Framework will Function

The silica dust and chemical irritants preventive framework is presented in Figure 6.1. The preventive framework feeds in the tradition project cycle which has four phases which are initiation; planning; implementation and execution; and closing. It is assumed and expected that all occupational health, safety and construction legal frameworks in Zambia were considered in the initiation and planning phases of the tradition project cycle. The framework will be suitable in all the four types of project delivery methods namely; design-bid-build, construction management at risk, design-build and integrated methods. The design – build entails that the client choses the designer who is also the contractor to work with the designs and then perform the construction too.

The most common project delivery method in Zambia is the design-bid-build where the client hires designers and engineers to complete everything up to bidding. The client then selects a contractor with the lowest price through the bidding process. The recommended project delivery method in terms of upholding occupational health and safety is the integrated method. The integrated method involves selecting of all the project stakeholders at the beginning of the project and include them in all the project plan especially the occupational health and safety plan of the project. The recommended construction stakeholders and the stages they are involved in are shown in Table 6.1. The model is suitable for all construction projects regardless of the size or project duration.

It is assumed that the appointments of the designers (architects), consulting engineers (quantity and land surveyors, civil engineers, structural engineers, electrical engineers, mechanical engineers) and the contractor were done using any of the project delivery methods according to the client's choice or preference. Based on this idea, the framework feeds in the implementation phase through to the closing phase in the project cycle. The framework is based on all occupational health, safety and construction legal frameworks in Zambia. It consists of three main stages with two sub-stages in each main stage. The main stages of the framework are preliminary prevention, enforcement prevention and execution prevention stages. The six sub-stages are pre-employment; induction and training; health and safety induction; tool box and risk assessment; work activity; and post work activity.

6.3.1 Preliminary Prevention Stage

During the project implementation phase, carrying out of works in terms of construction activities takes place, and money, time and human resource are the most used resources. However, these resources are all affected by occupational health and safety in one way or another. Therefore, it is key that the foundation for the ways of reducing exposure to silica dust and chemical irritants are practically introduced at this stage. The preliminary prevention stage will be the first stage which involves two sub-stages of pre-employment medical examination and training and induction.

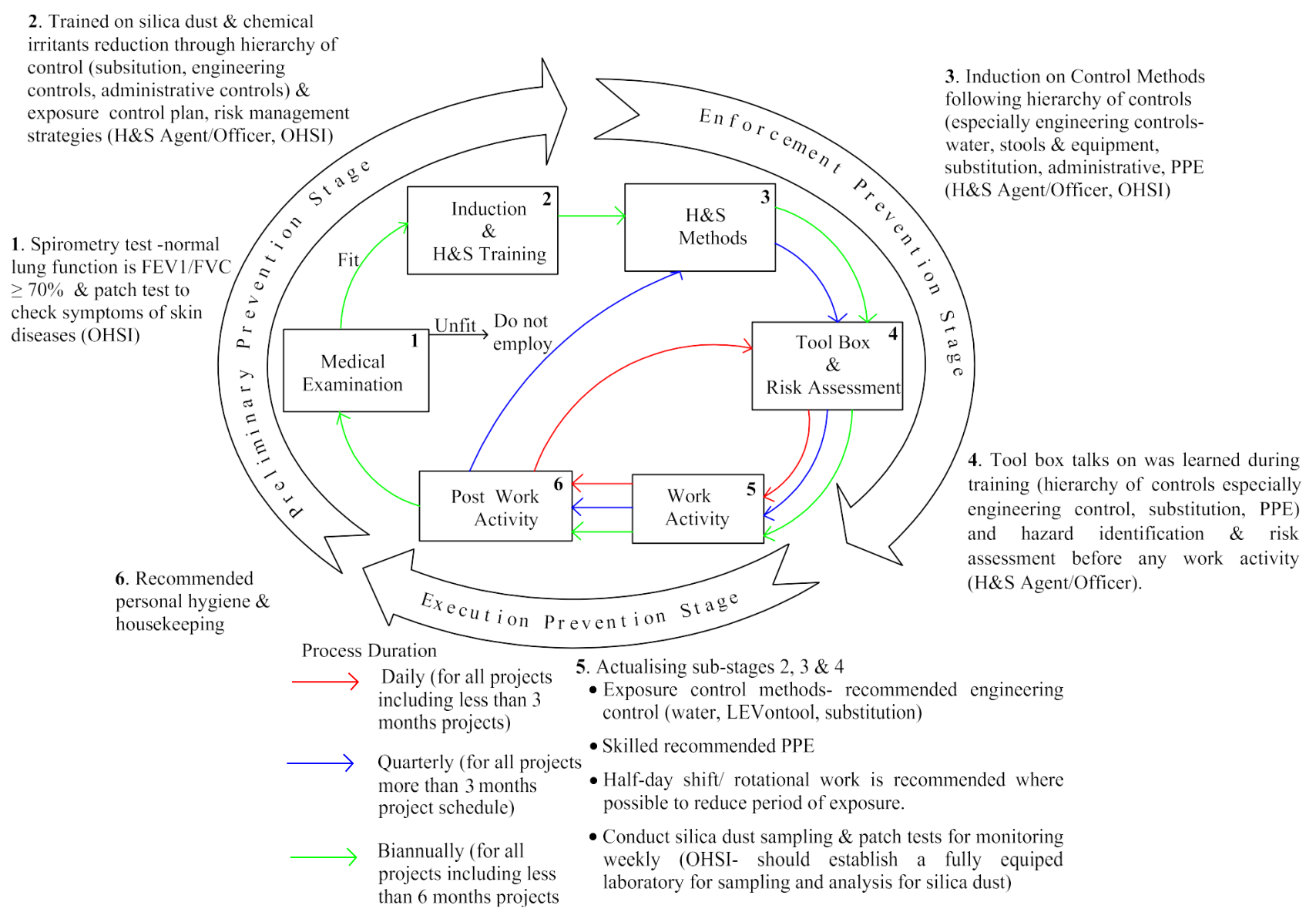


Figure 6.1: Integrated Preventive Framework Model

Table 6.1: Construction Stakeholder Involvement in the Preventive Framework

Construction Stakeholders	Preliminary Preventive Stage		Enforcement Preventive Stage		Execution Preventive Stage	
	Medical Examination	Induction & Training	H & S Methods	Toolbox & Risk Assessment	Work Activity	Post Work Activity
Client	√	√	√	√	√	√
Project Manager	√	√	√	√	√	√
Engineers	√	√	√	√	√	√
Architects Designers	√	√	√	√	√	√
Consulting Engineers	√	√	√	√	√	√
Civil Engineers	√	√	√	√	√	√
Electrical Engineers	√	√	√	√	√	√
Mechanical Engineers	√	√	√	√	√	√
Health & Safety Agent	√	√	√	√	√	√
Main Contractor	√	√	√	√	√	√
Subcontractors	√	√	√	√	√	√
Suppliers	√	√	√	√	√	√
Government Agencies	√	√	√	√	√	√
Health & Safety Officer	√	√	√	√	√	√
Health & Safety Committee	√	√	√	√	√	√
Skilled & Other Personnel	√	√	√	√	√	√
Community Representatives	√	√	√	√	√	√

i) Pre-Employment Medical Examination Sub-stage

This will be the first sub-stage where the construction specialised workers such as bricklayer, painters, carpenters, road workers and their labourers will undergo medical examinations before being employed. Moreover, other workers who are likely to be working in high exposure environment or activities, such as machine operators, tipper and other drivers will undertake the medical examination as well. In this sub-stage, the medical examination will be for lung function and skin examination. The lung function will be determined using spirometry tests to determine the lung functions whether they are normal or abnormal. The skin examination will be conducted using patching test to find the symptoms of skin diseases.

The lung function in terms of the ratio of Force Expiratory Volume in one second (FEV1) and Forced Vital Capacity (FVC) will be considered normal if it is greater than or equal to 70%. Any lung function tests less than 70% will be considered abnormal. If the medical examinations come out positive, that is if the lung function is abnormal or skin patch test shows symptoms of skin diseases, the answer is no. This means that the worker will not be employed for such tasks that have high silica dust and chemical irritants exposures. This is because, abnormal lung function may deteriorate easily with silica dust exposures and symptoms of skin diseases may lead to chronic skin diseases if there is more exposure to chemicals. If the tests come out negative, the answer is yes, the workers are fit to be employed. After the workers have been employed, they have to proceed to be trained and inducted in the second sub-stage. In addition, at this sub-stage, all the project team members who are likely to be exposed to silica dust and chemicals will undergo medical examination too. This means that the supervisors from consultants and contractors will undergo the medical examination. If they are not fit, they can be replaced by others who are fit from their companies to supervise high silica dust producing activities. The medical examinations will be conducted by the Occupational Health and Safety Institute (OHSI) who are mandated to perform such examinations by law (OHS Act, 2010).

ii) Induction and Training

This is sub-stage number two where the project team will be welcomed and made aware of their responsibilities on the project, health and safety plan, current health and safety legal requirements or frameworks and safe work procedures and exposure control plan during the training. Training will be on occupational health and safety issues such as the sources and dangers of silica dust and chemical irritants hazards, how to protect themselves and others and the preventive control methods accord to the hierarchy of controls, that are useful in reducing the exposures to silica dust and chemicals, the need for skill-suited and proper PPE, the importance of and how to conduct a risk assessment and the tool box talks. The importance of training in risk assessment at this stage is to ensure that all project players are familiar with risk strategies from inception and throughout the project cycle. This is recommended so that all project players take part in risk management for the benefits of human resource and the project at large. The training will also highlight the devastating

effects of respirable and skin diseases that are brought up by the silica dust and chemical irritant hazards. Workers will also be trained on benefits of their health and the project through good occupational health and safety performance.

During training, it will be emphasised that all the project team members, inclusive of workers, are expected not to eliminate or skip any health and safety stages and requirements. Such risk behaviour should be avoided and controlled at all times for effective reduction of hazards and risks. Training will be conducted by the health and safety agents and officers. The OHSI will also be part of the trainers depending on their availability as it is one of their core functions.

6.3.2 Enforcement Prevention Stage

The enforcement prevention involves the practical induction on health and safety methods; and toolbox talks and risk assessments.

i) Health and Safety Control Methods Induction

This is the sub-stage where induction of tools and equipment, control methods and recommended PPE will take place. Inspections of the tools and equipment will be conducted and certified fit and safe for use. Workers have to be trained or inducted on how to check the fitness of the tools and machines. Moreover, they have to be practically taken through step by step on how to use the tools, machines and control methods. The control methods should be according to the hierarchy of controls putting emphasis on the controls that adequately reduce exposures such as substitution and engineering controls. Furthermore, the combination of the different types of controls are recommended.

The recommended tools and equipment are

- Cutters, breakers, grinders should have on-tool LEV to extract dust at the source.
- Graders, water trucks, excavators, bulldozers, concrete trucks and trowels should be in good conditions and be clean or washed off the dust.
- Concrete and asphalt cutters should have a portable water container of connected to the water source so as to perform wet cutting which reduces dust emissions.

The recommended control methods are according to the hierarchy of controls and should be used in combination to adequately reduce exposures as recommended from findings of previous studies. Elimination method is the first one in the hierarchy of controls, nevertheless it is usually not possible when dealing with staple materials such as concrete, quarry dust, gravel and cement. Therefore, the recommended control methods in the framework are as follow:

- The use of substitution method of using tools which produce lesser exposure compared to when the activity is performed manually. The example is the use of mechanical demolition instead of manual demolition for reducing silica dust exposure and trowels instead of manual levelling on wet concrete for chemical irritants exposure.
- The engineering control is highly recommended as it reduces exposures meaningfully. The use of ventilation especially using LEV on-tools extraction of dust (built in). The example of the use of LEV on-tool is the use of a grinder with dust an extractor fixed on the tool. This means that dust which is being produced from grinding is extracted directly from the source.
- Water suppression- water keeps down the amount of dust polluting the air. Wet sanding, cutting, breaking and grinding is recommended. For outdoor projects, water is recommended to be sprayed three times per day.
- Spraying with water and covering of materials such as gravel and quarry dust on site and also when transporting such materials to prevent dust from escaping.
- Administrative control method which involves training and ensuring that the health and safety control plan is well implemented. Example of administrative control in the framework is ensuring that personnel works not more than four hours continuously on the activity that has high exposures.
- Practicing good housekeeping by ensuring that all remains of mortar and concrete are cleaned and cleared before they dry at the end of any work activity. This is another form of administrative control.

The suitable well-fitting and quality PPE is recommended such as:

- N95 respirators or any silica dust recommended respirators to prevent inhaling of silica dust.

- Skilled suited gloves- this is to ensure that chemicals or course dust do not penetrate through the gloves to the skin.
- Long sleeved work suits- this is to ensure that the body is not exposure to chemicals and dust.
- Quality gumboots- this is to ensure that no chemicals or concrete penetrate to the skin especially when working with wet works such as working with wet concrete.
- Goggles or face shields- to protect the eyes from dust and chemicals as these hazards may affect visibility.

Sub-stage number two should be conducted by the safety agent, occupational health and safety officer or any other qualified personnel.

ii) Toolbox Talks and Risk Assessments

After sub-stage three, the workers and the OHS personnel have to conduct the actual tool box talks and risk assessment before any daily activities in sub-stage four. Toolbox talks involve informal discussion that focuses on a particular health and safety issue to promote health and safety culture. Toolbox topics should be in line with the hazards associated to the task and activities that are on the programme for that day. The toolbox talks will serve as a reminder of what the workers learned during training and induction in sub-stage two. Tool box topics should be relevant to the work activities of the day such as hazard identification and control methods.

A risk assessment of the task or activity of the day is conducted in this sub-stage. A risk assessment is a process of hazard identification, analysis and evaluation of risks associated to the hazards identified. Job hazard analysis will be performed to identify hazards before they occur on a specific job activity. The activities with high exposure levels will be considered as first priority. The job hazards assessment require the involvement of the workers that are experienced in the particular activities as they are very familiar with the job. This is recommended as the workers will help identify hazards easily and will easily cooperate in the hazard controls since they will have a sense of being part of the process.

Sub-stage four will be carried out by the occupational health and safety officer, occupational health and safety committee representatives of the work gangs or groups. Moreover, other workers will be encouraged to carry out the toolbox talks and risk assessment under the guidance of the occupational health and safety officer. This will encourage good health and safety culture.

6.3.3 Execution Prevention Stage

The execution prevention stage requires the reduction of exposure at the beginning, during and end of the actual work activity, all through to after the end of the activity or task.

i) During the work activity (work activity)

This is the fifth sub-stage where sub-stage two, three and four feed in. This means that what was learned and conducted in second, third and fourth sub-stages will be actualised in this fifth sub-stage. The workers will be given and ensure that they use the recommended PPE, tools and equipment and materials and exposure reduction control methods. In this sub-stage, the skilled personnel will perform their work activities according to the recommended combination of control methods in the hierarchy of controls. This is to ensure that exposure reduction is meaningfully reduced in line with the findings by other researchers that a combination of all controls. The control methods according to the hierarchy as stipulated in the Health and Safety Control Methods Induction stage are;

- Elimination
- Substitution
- Engineering control
- Administrative control and
- Recommended, well-fitted PPE.

The starting point for this sub-stage is the recommended PPE suitable for each skill. Bricklayers, carpenters, painters, tilers, batchers, demolition workers, road workers and labourers for these skills have to wear skill and activity suited PPE. For example, bricklayers have to wear skilled approved gloves and gumboots so that chemicals do not penetrate the glove to the skin. Also to ensure that workers use proper recommend fit and safe tools and methods.

The results of this research and findings from other previous studies showed that the longer the period of exposure the higher the likelihood of workers developing symptoms of respirable and skin diseases. Therefore, workers have to work half day shift when working on high exposure activities. This means that they have to work not more than four hours continuously per day in higher exposures or perform an active that has high exposures to dust and chemical irritants. This is in order to reduce the period of exposure during one work shift. To ensure that production or project schedule is not affected, shift work is recommended or rotational work. This is where skilled workers and their labourers who are working in high exposure activities exchange with workers in low exposure activities after working for four hours in high exposure.

This is the sub-stage where it is recommended that silica dust measurements are conducted for the purposes of monitoring. Therefore, it is recommended that Zambia establishes a crystalline silica analysis laboratory through the OHSI and adopt the international exposure limits for effective monitoring to protect workers in all industries who are exposure to dust.

ii) Post work activity

This is the sixth sub-stage in the framework which involves aftermath assessment of risks which were identified during risk assessment in sub-stage four. Moreover, a review of controls used the work activity are evaluated against the hierarchy of controls. This will help to improve what was not properly done or not achieved as planned. Furthermore, this is the stage where assessment of nature of hands or feet after work is done. This activity is conducted to check the effectiveness of PPE like gloves and gumboots. The dirtier the hands or feet after work the likelihood of the occurrence of symptoms of skin diseases. This is because dirt hands were associated to high exposures according to the findings. In addition, symptoms of skin diseases or cement burns can occur even with one exposure.

At the end of each day or completion of the activities, workers will be required to wash their hands and face thoroughly to rinse off the dirty and dust. The workers have to remove the work suits and change in to their clean washable clothes. This is to reduce the period of exposure to dust and chemicals in that if their work suits

accumulated dust or chemicals, removing them would stop the exposure. This is true for all the PPE such as dust masks and gloves. If gloves are not removed at the end of the work activities, if some chemicals seeped into the gloves, having them on for a long time would mean continuous exposure. Therefore, by removing them and washing hands, reduces both the levels and period of exposure which are related to the prevalence of skin diseases. After the skin is washed thoroughly, petroleum should be applied. Petroleum is recommended to moisturize the skin and aid in the healing and restoration of skin wounds.

Good housekeeping is recommended to be practiced at the end of any work activity or task. Any leftover materials and chemicals will be disposed of properly and safely. The disposal of left over material should be in such a way that further exposure is avoided at all costs. Chemical seepages have to be well clean, solid or dust materials have to be wetted with water before sweeping so that dust is suppressed. Dust is not only harmful to workers but also to construction machines as dust can cause destruction quickly through tear and wear. This will increase machine operating costs as a result of frequency maintenance of construction. Therefore, to prevent the fast machine tear and wear, dust should be cleaned off the machines at the end of work activities. This sub-stage is for post activity prevention and is as equally important as the prevention or reduction of exposure during work activities. This sub-stage will be supervised by the occupational health and safety officer and the health and safety committee members or representatives.

6.4 Framework Model Processes

On a daily basis, the framework process at the last sub-stage which is the post activity, goes to sub-stage four which is toolbox and risk assessment. This means that the daily process has to begin with toolbox and risk assessment, where hazards are identified and the discussion on how to manage them. This is because it is a good health and safety practice to conduct tool box talks and risk assessment before any work activity. This will be followed by the work activity sub-stage where workers implement what was in the toolbox talks and risk assessment. Furthermore, this is the sub-stage where control methods which were learned and demonstrated how to use them in sub-stages two and three are put in to practice. In the case of a short project with less than three months' duration, workers have to be taught on the

control methods according to the hierarchy of controls. It is recommended that the daily process is conducted on all the projects regardless of the project duration, short or long, including any short term projects running from one day to the project completion date.

The quarterly process takes place every after three months and runs from health and safety methods sub-stage three through to toolbox and risk assessment sub-stage four, work activity sub-stage five to post activity sub-stage six. This is recommended to revise or amend the health and safety methods which involves the hierarchy of controls that have proved to be effective in the last three months. This process is recommended for projects of any kind that are more than three months.

Every after six months, a complete cycle is recommended. Biannual process starts from the medical examination sub-stage one, induction and H&S training sub-stage two, health and safety methods sub-stage three, toolbox and risk assessment sub-stage four, work activity sub-stage five to post activity sub-stage six. This is to establish how effective the preventive controls in reducing exposure to silica dust and chemical irritants were in regard to safeguarding the workers' health. It is after six months that it will be established if there are some workers who show symptoms of respiratory and skin diseases so that they are given other less or low silica dust and chemical irritant activities. This is to prevent the workers' health from deteriorating as the symptoms will be detected early thereby encouraging the workers' wellbeing. Moreover, it is law that after six months, workers must be given new PPE. Therefore, it is a good opportunity to review the exposure control plan and all health and safety guidelines for the project.

6.5 The Roles of Construction Stakeholders

For the framework to effectively work according to its purpose, there is need for teamwork of all the stakeholders in the construction industry. Teamwork, especially in health and safety improves health and safety culture on the overall construction project. In the preventive framework, each construction stakeholder will have their stipulated roles but are not limited to what is given as long as they are performed in a teamwork manner to reduce exposures to silica dust and chemical irritants in all the stages of the framework.

6.5.1 The Role of the Client

The clients either private or public have a big role of overseeing the project from initiation to closing as their objective is to get the desired product. In the preventive framework, clients are expected to have selected project team members or players who will ensure health and safety is upheld all through the project cycle. Regardless of any type of project delivery method used, the client will ensure the following in the framework:

- Ensure that all the local health and safety legal framework and international recommendations especially on silica dust and chemical irritants are followed throughout the project cycle through the project health and safety agent.
- Set the project health and safety objectives that s/he would want to achieve throughout the project especially the silica and chemical irritant exposure reduction.
- Select project managers who have demonstrated capabilities of ensuring that all project team members adhere to good health and quality throughout the project life cycle.
- Select a project safety agent to supervise all health and safety requirements on the project especially reduction of exposures to silica dust and chemical irritants.
- Select engineers (consulting engineers, architects, mechanical, electrical engineers) who are capable of ensuring that all designs, specifications, project documentations and eventually supervision uphold the recommended health and safety requirements.
- Select the contractors who are capable of executing the project as desired and as per designs and specifications taking into consideration all health and safety requirements and advice from the health and safety agent.
- Select suppliers who are capable of supplying machinery and materials that adhere to health and safety requirements and support the efforts of reducing exposure to silica dust and chemical irritants for project.
- Provide any financial requirement for reduction of silica dust and chemical irritants at all stages and sub-stages of the preventive framework.

- Demand comprehensive health and safety reports on all the plans and issues to do with silica dust and chemical irritant exposure reduction according to the exposure control plan from the health and safety agent and officer.

6.5.2 The Role of the Project Managers

In the case of clients who wish to select project managers to be in charge of the overall project from initiation to closing on behalf of the client, the project managers have to ensure the following:

- Ensure that all the local health and safety legal framework and international recommendations especially on silica dust and chemical irritants are followed throughout the project cycle.
- Select a project safety agent to supervise all health and safety requirements on the project including reduction of exposures to silica dust and chemical irritants in the project life cycle.
- Select engineers (consulting engineers, architects, mechanical, electrical engineers) who are capable of ensuring that all designs, specifications, project documentations and eventually supervision are in line with the recommended health and safety requirements from project initiation to closure.
- Advise the client on the need for financial requirement for upholding health and safety including reduction of silica dust and chemical irritants throughout the project life cycle especially at all stages and sub-stages of the preventive framework.
- Demand comprehensive health and safety reports on all the plans and issues to do with silica dust and chemical irritant exposure reduction according to the exposure control plan from the health and safety agent and officer.
- Select the contractor capable of executing the project as desired and as per designs and specifications taking into consideration all health and safety requirements and advice from the health and safety agent.
- Select suppliers who are capable of supplying machinery and materials that adhere to health and safety requirements and support the efforts of reducing exposure to silica dust and chemical irritants for project.

6.5.3 The Role of the Engineers

The engineers will mean architects, consulting engineers, structural engineers, electrical engineers and mechanical engineers. The role of the engineers in the preventive framework will be the following:

a) Architects and Designers

Architects and designers have to ensure that their designs incorporate materials and activities that encourage reduction of exposure to silica dust and chemical irritants. They have to encourage and propose the use of less silica content materials or substitute high silica content materials or activities. Example is the use of cladding the building in place of painting which requires use of sand for plastering and wall filling which are high silica dust activities.

b) Consulting and Structural Engineers

Consulting and Structural engineers have to ensure that they recommend in the designs and specifications, the use of less silica content materials, encourage methods that produce less silica dust and methods that reduce exposure to chemicals. They have to ensure that during the construction stage, silica dust and chemical irritant control methods are properly followed by the contractor as they supervisor the works.

c) Electrical and Mechanical Engineers

The electrical and mechanical engineers have to ensure that they adhere to the health and safety requirements for the project. Likewise, they have to use silica dust reduction methods as they perform their part on the project. One of the things electrical and mechanical engineers should avoid chiselling and drilling in the walls when they can use a better and safer method of putting the electrical conduit tubes as bricklayers are building walls. Further, they should use wet drilling to reduce silica dust exposures.

6.5.4 The Role of the Health and Safety Agent

The health and safety agent is selected by the client or the project managers depending on the project delivery method the client wishes to use. The health and safety agent will be in charge of all health and safety for the entire project from

initiation to closure. In the preventive framework, the health and safety agent will be in charge of overseeing that all the stages and sub-stages are conducted in an effective manner to achieve the goal of silica dust and chemical irritant exposure reduction. The health and safety agent will prepare a written exposure control plan and ensure that it is well implemented. Moreover, s/he will ensure that the client handles all the financial implications at all stages and sub-stages of the preventive framework. This means that s/he has to ensure that all workers' medical examinations in the preliminary preventive stage and all the exposure control measures are budgeted for in the bill of quantities under health and safety item as a lump sum. S/he is in charge of supervising the health and safety officer.

6.5.5 The Role of the Contractor, subcontractors and suppliers

The contractor has to ensure that the health and safety plan they submitted at tendering stage is improved upon and used effectively throughout the project. The contractor has to ensure that the health and safety plan matches its financial implication so that it is easy to actualise on site especially during the framework stages. The contractor has to adhere to the health and safety requirements and recommendations of the safety agent and officer. Also, the contractor has to employ a competent health and safety officer to ensure that all the health and safety requirements on site are well executed and enforced. The contractor has to ensure that health and safety subcontractors and suppliers adhere to the health and health plan.

6.5.6 The Role of Government and its agencies

The government is sometimes the client for public projects and therefore will have a role of the client in the preventive framework. In the case where the project is private, the government through its agencies ensure that all the legal requirements are adhered to from the project initiation to the project closing. This means that government agencies will be available at all stages in the preventive framework. In addition, government should empower OHSI by establishing the silica dust sampling and analysis laboratory in Zambia and set the silica dust permissible level to effectively monitor exposure levels. This will help in safeguarding the workers' health in all sectors of the nation.

(a) Occupational Health and Safety Institute

The Occupational Health and Safety Institute (OHSI) have a responsibility to ensure that the OHS Act of 2010 is enforced in all sectors including construction industry. The OHS Act of 2010 incorporates other legal framework that pertain to health and safety such as the Factories Act and the NCC Act. This means that the Zambian legal frameworks given in section 2.2.2 are enforced together with the OHS Act of 2010. The inspectors and officers from OHSI and the other local frameworks will be allowed to conduct inspections throughout the framework cycle according to their legal obligations and mandates in safeguarding health and safety. In the preventive framework, the OHSI under its functions as stipulated in the OHS Act of 2010, will do the following:

- Ensure that the medical examinations for lung functions and skin tests are conducted in the preliminary prevention stage and sub-stage one.
- Be part of offering training on health and safety in sub-stage two.
- Help in the health and safety methods and tool box and risk assessment in sub-stages three and four in order to eliminate or reduce silica dust and chemical irritant hazards.
- Carry out silica dust measurements and patch tests during the work activity sub-stage to monitor if the silica dust and chemical exposure levels are reducing with the use of recommended control methods in the preventive framework.
- Carry out research on other ways of eliminating silica dust and chemical irritant hazards.
- Establish the silica dust sampling and analysis laboratory in Zambia to effectively monitor and control exposures as one of their functions is to provide occupational laboratory services.

The OHSI will be available at all stages and sub-stages of the preventive framework according to their legal responsibilities as stipulated in the OHS Act of 2010. Moreover, the OHSI has to set its permissible exposure limits for silica and respirable dust that are comparable to the international standards. The international standards that are recommended in the preventive framework are the OSHA PELs. Zambia still uses $1.74\text{mg}/\text{m}^3$ as the legal limit for general dust which puts workers

at a high risk of developing respiratory diseases. The Zambian legal limit is 34 times more than the OSHA PEL for silica dust ($0.05\text{mg}/\text{m}^3$) despite it being 2.8 times less than PEL for respirable dust ($5\text{mg}/\text{m}^3$). The most important dust hazard is silica dust as it causes silicosis which is scouring of the lungs and has no cure.

(b) Other Government Agencies

There are several other government institutions or agencies that are directly or indirectly mandated to inspect, supervise or oversee construction and health and safety concerns. Some notable agencies are;

- National Council for Construction (NCC)
- Workers Compensation Control Board (WCCB)
- Zambia Environmental Management Agency (ZEMA)
- Ministry of Labour (MoL)

These agencies will be available throughout the preventive framework cycle at any stage as they carry out their respective legal functions which are related to safeguarding the workers wellbeing and the quality of construction works.

6.5.7 The Role of Health and Safety Officer and Committees

The health and safety officer is engaged by the contractor to ensure all the health and safety requirements for the project are well executed according to the contractor's health and safety plan. The role of the health and safety officer in the preventive framework is to ensure that all the stages and sub-stages are well carried out to achieve the purpose of reducing exposures to silica dust and chemical irritants to safeguard the workers and the project. The health and safety officer has to be available all through the preventive framework cycle and is responsible of implementing and enforcing the exposure control plan. S/he has to be part of the workers to undergo the medical examinations as s/he will be supervising the other stages and sub-stages. S/he will be supervised by the health and safety agent. The health and safety officer will ensure that all the planned project health and safety issues, guidelines and policies are implemented and enforced on the construction site accordingly. S/he has to be fully available on site to handle any health and safety concerns and ensure that workers and all project team members adhere to health and safety guidelines.

The health and safety committee members by the guidance of the health and safety officer will perform the following:

- Promote good relationship between the contractor and the workers in achieving the health and safety project goals through the formulating, reviewing and disseminating the health and safety rules, plans and procedures.
- Carry out hazard identification, risk assessment and tool box talks before the work activity sub-stage.
- Ensure that all workers follow all the health and safety recommendations for silica dust and chemical irritant exposure reduction throughout the preventive framework cycle.
- Encourage all the workers to properly use the recommended PPE for the work activity such as N95 dust masks, gumboots, goggles and skill or activity suited gloves.

6.5.8 The Role of Skilled and other Personnel

The skilled workers and other personnel have to adhere to all health and safety requirements of the project. In the preventive framework, workers and other personnel will undergo medical examinations and when they are certified fit, they proceed to the induction and training stages. The skilled workers and other personnel in sub-stage five, are required to put into practice all the lessons learned from sub-stages two, three and four. They have to ensure all the control methods are put into practice by complying with the exposure control plan. They have to wear the appropriate PPE recommended in reduction of exposures to silica dust and chemical irritants. In addition, they have to cooperate with the health and safety officer and the committee to properly improve or safeguard their well-being. The skilled and other workers will also be part of hazard identification and tool box talks so that they learn and feel a sense of responsibility. This will encourage good health and safety practice and improve health and safety culture.

6.5.9 The Role of the Community Representatives

The community where the project is taking place are part of the construction stakeholders. In the preventive framework, the community will be represented by

the local champions, headmen, chiefs and religious leaders. These are the people who have influence in the community and are well respected. These will represent the community in the preventive framework to ensure that the purpose of the health and safety goals are achieved in safeguarding the workers and the community. It is important that the community is representation in the health and safety meetings because some of the workers will be tested and employed from the community and the silica dust and chemical exposures affect the community. Moreover, the community representatives have to make sure that the health and safety and exposure control plans for the project meet the community expectations (Mwanaumo, 2012).

6.6 Framework Validation Process

The developed preventive framework had to undergo validation to test its functionality, validity and usefulness. The validation questionnaire is attached in the appendices. The validation process involved purposively sampling of the construction experts and stakeholders. The construction stakeholders who participated in the preventive framework model validation were either involved in the construction project cycle or they were in charge of occupational health and safety. Twenty experts were purposively sampled to help in assessing if the preventive framework would achieve its purpose in real construction project cycle. The questionnaire was accompanied by an introductory letter and the research abstract. The research abstract was included to give a guide of what the study was about, the methods used and the results of the research. This was because the experts were not involved in the research during data collection, therefore they needed to have the background information. The data collection was focused on the skilled personnel in order to get the correct information from individuals who were exposed to silica dust and chemical irritants.

A 5-point Likert scale was used, where strongly disagree was 1, disagree was 2, not sure was 3, agree was 4 and strongly agree was 5. In addition, the respondents were asked to give an overall score for the model where very bad was 1, bad was 2, fair was 3, good was 4 and very good was 5. The validation questions covered the following aspects of the framework;

- Preliminary prevention

- Enforcement prevention
- Execution prevention
- Process duration
- Model assessment

6.7 Validation Results and Discussion

The validation data was analysed using SPSS using descriptive statistics. The average means for the validation questions and statements were close to the average medians. The questions and statements with the means less than the medians, indicate the measure of distortion of symmetric to the left giving a negative skewness. On the other hand, the questions and statements that recorded the means greater than the medians, had the measure of distortion of symmetric to the right as shown in Table 6.2. Moreover, all the standard deviations were within $\pm 2SD$ signifying that values were closer to the true value. This indicates the validity of the results for validation process.

The validation data was analysed and tested for significance by means of One-Sample Test using 3.5 as the test value as explained in chapter three section 3.3.7.

6.7.1 Profile of Framework Model Validation Respondents

The response rate was 60% as 12 experts responded out of the 20 who were targeted. The results by gender were 25% females and 75% males. This was similar to the questionnaire results that showed that there were more males in the construction industry compared females. There were five types of construction stakeholder groups the experts responded belonged to. There were 33% H&S agents or specialists, 25% government agencies, 17% engineers, 17% contractors and 8% clients as shown in Figure 6.2. This was a representative of the key construction stakeholders that have influence in the construction industry.

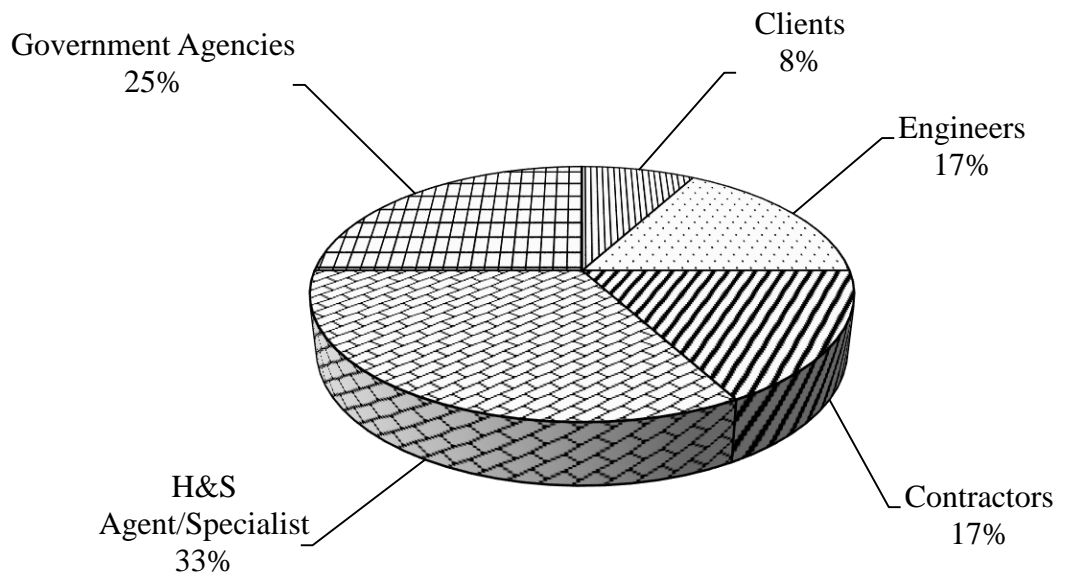


Figure 6.2: Respondents' Type of Construction Stakeholder Group

Table 6.2: Validity of Framework Model Validation Results

Item	Questions/Statements	Mean	Median	Std. Deviation	Skewness
1	What is your gender?	1.25	1.00	0.45	1.33
2	What type of construction stakeholders do you belong to?	4.42	5.00	1.51	-1.06
3	Conducting medical examination will help detect the symptoms early and encourage workers' health.	4.83	5.00	0.39	-2.05
4	Induction and training of project team on all H&S will help protect themselves from hazards.	4.75	5.00	0.62	-2.55
5	Practically inducting workers in the use of tools, control methods will help them reduce exposure.	4.83	5.00	0.39	-2.05
6	Showing workers how to conduct tool box talks and risk assessment will help them adhere to H&S.	4.83	5.00	0.39	-2.05
7	Ensuring that workers perform their work activities according to the recommended control methods and tools will help reduce exposure &review exposure control plan and methods.	4.67	5.00	0.65	-1.93
8	Practicing personal hygiene and housekeeping will reduce the period of exposure to dust and chemicals thereby protecting the workers from further exposure.	4.08	4.00	0.90	-1.08
9	Practicing personal hygiene and housekeeping will reduce the period of exposure or further exposure.	4.83	5.00	0.39	-2.05
10	Quarterly process will help revise controls on how effective they have been in the last three months.	4.08	4.00	0.51	0.21
11	Biannually process will help establish how effective the preventive controls have been in reducing exposure to silica dust and chemical irritants in regard to safeguarding the workers' health.	4.41	4.00	0.51	0.39
12	The model can help reduce exposure to silica dust and chemical irritants.	4.50	4.50	0.52	0.00
13	The model has integrated aspects that may work well to reduce silica dust and chemical irritants.	4.33	4.00	0.65	-0.44
14	The approaches in the model on silica dust and chemical irritant controls are familiar.	3.50	3.50	1.00	0.00
15	The model is easy to understand and follow.	4.41	4.00	0.51	0.39
16	The preventive stages identified in the model can improve silica dust and chemical irritants controls.	4.41	5.00	0.79	-0.99
17	The relationship among the sub-stages are clear.	4.33	4.00	0.65	-0.44
18	The proper use of the model could help reduce exposure to silica dust and chemical irritants.	4.33	4.00	0.65	-0.44
19	Proper use of the model could improve overall health and safety culture of construction stakeholders.	4.58	5.00	0.67	-1.45
20	What is your overall rate of the model?	4.42	4.00	0.51	0.39

6.7.2 Framework Model Characteristics Results

The framework model characteristics were assessed by respondents and the analysed results are shown in Table 6.3. All the characteristics were statistically significant as all the three parameters in section 3.3.7 for significance in One-Sample Test were met of t greater than CV, ρ -values less than 0.05 and the 95% confidence interval of the difference not crossing the zero. This means that all the characteristics of the framework model were considered important and useful in reducing exposures to silica dust and chemical irritants.

Table 6.3: Framework Model Characteristics One-Sample Test Results

	Test Value = 3.5					
	t	df	ρ	CV	95% Confidence Interval of the Difference	
					Lower	Upper
Conducting medical examination for lung function and skin before employing workers will help detect the symptoms early thereby encouraging the workers' health.	11.87	11	0.00	2.20	1.09	1.58
Induction and training of project team on their responsibilities, health & safety plan, current health & safety legal frameworks and exposure control plan will help them to know the dangers and to protect themselves from silica dust and chemical irritants.	6.97	11	0.00	2.20	0.86	1.64
Practically taking the workers through the use of tools, control methods will help them know how to reduce exposure to silica dust and chemical irritants.	11.87	11	0.00	2.20	1.09	1.58
Showing workers how to conduct tool box talks and risk assessment will help them to adhere to health and safe practices towards reduction of exposure to silica dust and chemical irritants.	11.87	11	0.00	2.20	1.09	1.58
Ensuring that workers perform their work activities according to the recommended control methods and tools will help reduce exposure and review exposure control plan and methods.	6.20	11	0.00	2.20	0.75	1.58
Practicing personal hygiene and housekeeping will reduce the period of exposure to dust and chemicals thereby protecting the workers from further exposure.	2.24	11	0.05	2.20	0.01	1.16

The respondents agreed that the following were important in mitigating silica dust and chemical exposures:

- Conducting medical examination for lung function and skin before employing workers will help detect the symptoms early thereby encouraging the workers' health.
- Induction and training of project team on their responsibilities, health & safety plan, current health & safety legal frameworks and exposure control plan will help them to know the dangers and to protect themselves from silica dust and chemical irritants.
- Practically taking the workers through the use of tools, control methods will help them know how to reduce exposure to silica dust and chemical irritants.
- Showing workers how to conduct tool box talks and risk assessment will help them to adhere to health and safe practices towards reduction of exposure to silica dust and chemical irritants.
- Ensuring that workers perform their work activities according to the recommended control methods and tools will help reduce exposure and review exposure control plan and methods.
- Practicing personal hygiene and housekeeping will reduce the period of exposure to dust and chemicals thereby protecting the workers from further exposure.

6.7.3 Framework Model Process Durations

The framework model processes were assessed in the validation if they were important in reducing exposures to silica dust and chemical irritants. Using One Sample Test, the results showed that all the three process duration were statistically significant as shown in Table 6.4. Respondents agreed that the three process duration which were proposed in the preventive framework model were important in mitigating silica dust and chemical irritants exposures. The proposed process durations were as follows:

- Conducting tool box talks and risk assessment daily before any work activity will help encourage good health and safety practice.
- Repeating the sub-stages 3 (health and safety methods) all through to 6 (post work activity) quarterly (every after three months) will help revise or amend

the controls on how effective they have been in the last three months. This quarterly process is recommended for any project which is more than three months.

- Repeating the complete cycle biannually that is every after six months will help establish how effective the preventive controls have been in reducing exposure to silica dust and chemical irritants in regard to safeguarding the workers' health.

Table 6.4: Framework Model Process Duration One-Sample Test Results

	Test Value = 3.5					
	t	df	ρ	CV	95% Confidence Interval of the Difference	
					Lower	Upper
Conducting tool box talks and risk assessment daily before any work activity will help encourage good health and safety practice.	11.87	11	0.00	2.20	1.09	1.58
Repeating the sub-stages 3 (health and safety methods) to 6 (post work activity) quarterly (every after three months) will help revise or amend the controls on how effective they have been in the last three months.	3.92	11	0.00	2.20	0.26	0.91
Repeating the complete cycle biannually will help establish how effective the preventive controls have been in reducing exposure to silica dust and chemical irritants in regard to safeguarding the workers' health.	6.17	11	0.00	2.20	0.59	1.24

6.7.4 Framework Model Assessment

The integrated preventive framework model was assessed by respondents in terms of its functionality, validity and usefulness. One-Sample Test was used to find the significance of the responses from respondents and the results are presented in Table 6.5.

i) Functionality of the integrated preventive Framework Model

Three characteristics were posed to test the functionality of the framework model which was developed. Two characteristics were statistically significant as their t was greater than the CV, p-values were less than 0.05 and the 95% confidence interval of

the difference did not cross the zero. One characteristic on how familiar the model approaches was not statistically significant. This may be one of the reasons why there were high exposure levels to silica dust and chemical irritants in the construction industry as the approaches used in the model have been shown to be effective in reducing exposures in several studies. Therefore, training and sensitization on the model approaches should be recommended so that construction stakeholders become familiar with the controls of silica dust and chemical irritants.

Table 6.5: Assessment of the Integrated Framework Model

	Test Value = 3.5					
	t	Df	ρ	CV	95% Confidence Interval of the Difference	
					Lower	Upper
Functionality						
The model can help reduce exposure to silica dust and chemical irritants.	6.63	11	0.00	2.20	0.67	1.33
The model has integrated aspects that may work well to reduce silica dust and chemical irritants.	4.43	11	0.00	2.20	0.42	1.25
The approaches in the model on silica dust and chemical irritant controls are familiar.	0.00	11	1.00	2.20	-0.64	0.64
Validity						
The model is easy to understand and follow.	6.17	11	0.00	2.20	0.59	1.24
The preventive stages identified in the model can improve silica dust and chemical irritants controls.	4.00	11	0.00	2.20	0.41	1.42
The relationship among the sub-stages are clear.	4.43	11	0.00	2.20	0.42	1.25
Usefulness						
The proper use of the model could help reduce exposure to silica dust and chemical irritants.	4.43	11	0.00	2.20	0.42	1.25
Proper use of the model could improve overall health and safety culture of construction stakeholders.	5.61	11	0.00	2.20	0.66	1.51

Moreover, this is an important issue to take note before the framework model is used, sensitization and training should be conducted to ensure the approaches for control for silica dust and chemical irritants exposures are well known by construction

stakeholders. In addition, from the hierarchy of controls, administrative control is recommended for all the strategies or approaches for control are taught and known. Consequently, the functionality of the model was calculated at 67% which was still high.

ii) Validity of the Integrated Preventive Framework Model

The framework model was tested for validity in terms of logical and factual. All the characteristics for validity were statistically significant using One-Sample Test as their t was greater than CV which was found in the student's distribution table, ρ -values were less than 0.05 and the 95% confidence intervals of the difference did not cross the zero. Hence the results showed high validity.

iii) Usefulness of the Integrated Preventive Framework Model

The validation respondents also assessed the framework model on its usefulness. The respondents agreed that the proper use of the model could help reduce exposure to silica dust and chemical irritants and overall improve health and safety culture in construction. The results were tested using One-Sample Test for significance and all the characteristics were statistically significant as their t was greater than CV, ρ -values were less than 0.05 and the 95% confidence intervals of the difference did not cross the zero. Thus, the preventive framework model was highly useful.

iv) Overall Rating of the Integrated Preventive Framework Model

The respondents were asked to rate the model using the following:

- Poor as 1
- Fair as 2
- Good as 3
- Very good as 4 and
- Excellent as 5

The results of the frequency table for the overall rating of the framework model is shown in Table 6.6. The overall rating was very good as 58.3% of the respondents agreed that the model is very good. Furthermore, the results were tested for significance using One-Sample Test using the mean of 3.5. The results were statistically significant as the t was greater than CV, ρ -values were less than 0.05

and the 95% confidence intervals of the difference did not cross the zero as presented in Table 6.7.

Table 6.6: Overall Rating of the Integrated Preventive Framework Model

		Frequency	Valid Percent	Cumulative Percent
Valid	Very good	7	58.3	58.3
	Excellent	5	41.7	100.0
	Total	12	100.0	

Table 6.7: Overall Rating of the Framework Model

	Test Value = 3.5					
	t	df	ρ	CV	95% Confidence Interval of the Difference	
					Lower	Upper
What is your overall rate of the model?	6.17	11.00	0.00	2.20	0.59	1.24

6.7.5 Suggestions for Improvements on the Framework Model

The respondents were asked to generally comment on the framework model in their own words as this was an open ended question. The comments were taken in to consideration to improve the framework model and some comments were recommendations. The following were the comments for improvements:

- i) Risk assessment should be a continuous process and if done even in the initial stages of the framework, can help achieve the desired results faster. This is because it helps every actor on the project to include risk management strategies early enough in the project cycle.
- ii) Site visits should be conducted to assess the model in terms of compliance.
- iii) Apart from focusing on administrative controls which is awareness, induction and trainings, in the hierarchy of control of hazards, the framework model should also emphasize important aspect of engineering control especially regarding dust and chemical exposure. The idea is to reduce exposure as much as possible before PPE is used. The reality in the construction industry is that both training of project teams and showing them how to perform control methods are important.

- iv) Ensuring that the model suits all projects short or long to warrant that no activity or worker is left out is paramount in silica dust and chemical irritant exposure reduction.
- v) Dust monitoring equipment should be available for sampling and results analysed on a weekly or monthly basis if possible
- vi) Physical demonstration of the model and organise sensitization of the model on various media should be encouraged.
- vii) The practical use of control methods on sites should be emphasized to help reduce exposures to silica dust and chemical irritants.

6.8 Summary

In this chapter, the framework was developed from the literature review and the findings of the study. All the strategies and parts of the framework were explained. The beginning to the end of the framework, emphasis was on the silica dust and chemical irritant controls and safeguarding workers' health. The developed an integrated preventive framework model was validated using the experts and the functionality, usefulness and validity were significant and upheld by the experts.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The previous chapter presented the development of an integrated preventive framework model and its validation process. This chapter gives the conclusions and recommendations of the research. Moreover, it presents the research summary and how the objectives were achieved, the contribution of the research to the body of knowledge, research implications, limitation of the research and recommendations for further research.

7.2 Research Summary

The research introduction was given in Chapter One where objectives were listed. Chapter Two presented the critical literature review in line with the research objectives and the research hypotheses and the theoretical framework which resulted from integration of Theory of Work Adjustment and Domino Safety Theory. The independent variables were exposure to silica dust and chemical irritants while the dependent variables were symptoms of respiratory and skin diseases in the conceptual framework.

The research design which explained how the research was conducted, from methods, instruments and data analysis was presented in Chapter Three. Two case studies The results and testing of the research hypotheses were presented in Chapter Four. The discussion of the findings in relation to the previous studies followed in Chapter Five. The development and validation of an integrated preventive framework for construction personnel exposed to silica dust and chemical irritants which resulted from the literature review and the results were presented in Chapter Six.

7.3 How Research Objectives Were Achieved

The air sampling and laboratory analysis was conducted to achieve objective number one. The second, third and fourth objectives were achieved through the questionnaire survey using 100 purposively sampled skilled workers on which observation was conducted with the aid of observation schedule and the photographs. The last objective of developing an integrated preventive framework was realised from the

literature review and the findings of the research. The framework model was validated by 12 construction stakeholder experts through a questionnaire survey.

7.3.1 Evaluation of Research Objective Number One

To establish levels of silica dust construction specialised personnel were exposed to in relation to OSHA PEL ($0.05\text{mg}/\text{m}^3$).

The first research objective dwelt on establishing levels of silica dust construction specialised personnel were exposed to compared to the known concentration of $0.05\text{mg}/\text{m}^3$. Inhaling silica dust above the concentration of $0.05\text{mg}/\text{m}^3$ have been proved to be harmful and can lead to respiratory diseases such as chronic obstructive pulmonary disease, renal disease, tuberculosis, lung cancer and silicosis. The worst of the diseases is silicosis which is lethal and has no known cure. The research results showed that the silica dust levels construction specialised personnel were exposed to were above OSHA PEL of $0.05\text{mg}/\text{m}^3$. This means that the bricklayers, carpenters, batchers, tilers, demolition workers, painters, handymen and road construction workers in the construction industry in Zambia were exposed to high silica levels that were harmful to their health.

The following results were also established from the air sampling for silica dust and respirable dust:

- i) The highest individual concentrations for RCS was $1.58\text{mg}/\text{m}^3$ which is 96% higher than OSHA PEL ($0.05\text{ mg}/\text{m}^3$).
- ii) The highest individual concentrations for respirable dust was $23.19\text{mg}/\text{m}^3$ which is 78% higher than OSHA PEL ($5\text{ mg}/\text{m}^3$).
- iii) Carpenters recorded highest individual concentrations of silica dust and respirable dust.
- iv) There was no relationship between the job title and the levels of exposures to silica dust and respirable dust.
- v) On the individual silica dust exposures, 40% were above the OSHA PEL.
- vi) The AM for silica dust exposure level was $0.228\text{mg}/\text{m}^3$ which was 78% more than OSHA PEL.
- vii) The overall GM for silica dust was $0.04\text{mg}/\text{m}^3$ which was 20% less than OSHA PEL of $0.05\text{mg}/\text{m}^3$

7.3.2 Evaluation of Research Objective Number Two

To assess the dust levels in relation to the prevalence of symptoms of respirable diseases.

Previous studies have shown that occurrence of symptoms of respiratory diseases depend on the silica dust exposure levels and period of exposure. When silica dust exposure levels are high, the symptoms of respiratory diseases tend to develop faster. On the other hand, the longer someone gets exposed to low levels of silica dust, the longer it takes for symptoms of respiratory diseases to manifest. The second research objective was assessed using the respondents' responses from the questionnaire. Findings revealed that in spite of high levels of dust exposures from silica dust sampling, questionnaires and observation, the dust levels were not related to prevalence of symptoms of respirable diseases. The study showed that 92% of respondents experienced symptoms of respirable diseases and 86% of respondents experienced coughing.

7.3.3 Evaluation of Research Objective Number Three

To determine the levels and period of exposure to chemical irritants in relation to prevalence of symptoms of skin disease for construction specialised personnel in Zambia.

The levels and period of exposure to chemical irritants is important in the occurrence of symptoms of skin diseases. The higher the levels of exposure to chemical irritants the higher the likelihood of developing symptoms of skin diseases. Likewise, the longer the period of exposure to chemical irritants the higher the likelihood of developing symptoms of skin diseases.

There was a relationship between levels of exposure to chemical irritants the occurrence of symptoms to skin diseases. There was also a relationship between period of exposure to chemical irritants and occurrence of symptoms to skin diseases. This means that the more workers are exposed to high levels of chemical irritants and the longer the period of exposure, the higher the likelihood of them developing symptoms of skin diseases.

The exposure to chemical irritants in construction was high as 85% of respondents experienced high exposures. There was a 78% prevalence of the symptoms of the skin diseases among the skilled in both road and building construction workers. The study established that 39% of respondents had experienced scaly hands as the common symptom of skin diseases and 54% of them experienced the symptoms more than three times. Most respondents (71%) reported that symptoms lasted within three weeks after stoppage or discontinued exposure.

7.3.3 Evaluation of Research Objective Number Four

To identify current existing controls for silica dust and chemical irritants in relation to prevalence of symptoms of respirable and skin diseases.

Previous studies showed that the combination of controls from the hierarchy of controls effectively reduce exposures. This study showed that from the hierarchy of controls, only two controls were commonly used for silica dust: water which is part of engineering control and dust masks which are part of PPE. Unfortunately, the common masks that were used were Covid-19 masks which are not recommended for silica dust control. There was a relationship between the controls used on site and the prevalence of respiratory diseases. It can be concluded that the less adequate the controls, the more prevalent the symptoms of respiratory diseases.

Wearing of gloves, gumboots, work suits, washing of hands and application of hand cream (petroleum jelly) were the common controls used on sites. The study established that there is a relationship between controls used for chemical irritants and prevalence of symptoms of skin diseases. There was a negative correlation between prevalence of symptoms of skin disease, the frequency of wearing gloves (-0.347) and the wearing of gumboots and work suits (-0.363) respectively. This meant that the more frequent, the suitable and well fitted gloves were worn, the less prevalence the symptoms of skin diseases. Likewise, the more quality and suitable gumboots and work suits were worn, the less the prevalence of skin diseases. This was supported by findings of 42% of respondents who did not have gloves and the 78% prevalence of symptoms of skin diseases. This meant that they were more exposed to chemical irritants and eventually develop symptoms of skin diseases.

The positive correlation between nature of hands after work and the prevalence of symptoms of skin diseases (0.237) meant that the dirtier the hands are after work the higher the likelihood of developing symptoms of skin diseases because dirtier hands after work meant workers were exposed to higher levels of chemical irritants.

7.3.5 Evaluation of Research Objective Number Five

To develop an integrated preventive framework for specialised construction site personnel exposed to silica dust and chemical irritants and validate it.

From the findings of the study and critical literature review, an integrated framework was developed. It introduced and incorporated preventive strategies to reduce exposures to silica dust and chemical irritants in the traditional project cycle.

Characteristics that guided the developments of an integrated preventive framework were as follows;

- i) The silica dust levels the construction specialised workers were exposed to were above OSHA PEL of $0.05\text{mg}/\text{m}^3$ and could lead to symptoms of respiratory diseases.
- ii) The levels and period of exposure to chemical irritants was related to occurrence of symptoms of skin diseases.
- iii) The high prevalence of symptoms of respiratory diseases (92%) and skin diseases.
- iv) The controls used on sites for both silica dust and chemical irritants were inadequate and were related to the occurrence of symptoms of respiratory and skin diseases.
- v) The combination of all controls in the hierarchy of control effectively reduced exposures. In terms of silica dust, the combination of controls reduces exposures to below OSHA PEL of $0.05\text{mg}/\text{m}^3$.
- vi) The framework is based on all occupational health, safety and construction legal frameworks in Zambia. Moreover, it is line with Sustainable Development Goals number three of achieving good health and well-being by 2023 by way of reducing a number of deaths and illnesses caused by hazardous chemical and air pollution and contamination.
- vii) Exposure reduction to silica dust and chemical irritants begins from the start of the project in all the types of project delivery methods. It incorporates all

the construction stakeholders and project team and their roles in silica dust and chemical irritant exposure reduction.

- viii) Screening the workers and project team for lung function and symptoms of skin diseases helps to avoid abnormal lung function which may deteriorate easily with silica dust exposures and symptoms of skin diseases may lead to chronic skin diseases if there is more exposure to chemicals. Therefore, workers who fail the medical examination are not supposed to be employed in such high exposure activities. They should be employed to work in construction activities that have less exposures to silica dust and chemical irritants.
- ix) Training and induction of the workers and project team is important for them to be aware of health and safety concerning silica dust and chemical irritants control.
- x) Practical learning of exposure control methods in the hierarchy of controls and emphasis on engineering control which reduces exposures meaningfully.
- xi) Carrying out the tool box talks and risk assessments daily before any work activity.
- xii) Implementing or employing of all the silica dust and chemical irritants control methods as they carry out activities.
- xiii) Conduct silica dust sampling to monitor exposures.
- xiv) Encourage rotational work whenever possible to ensure that period of exposure is reduced to four hours for high exposure activities to avoid continuous exposures.
- xv) Encourage good housekeeping and personal hygiene to reduce both levels of exposure and period of exposure.

The study established from validation findings that the framework model would help reduce exposure to silica dust and chemical irritants. The 12 construction experts from different organizations upheld the functionality, validity and usefulness of the framework model. Generally, the framework shows how all construction stakeholders can participate in silica dust and chemical irritants exposure reduction by using the recommended strategies in order to safeguard workers' health and the projects.

7.4 Research Contribution to the body of Knowledge

In this research, the concentrations of silica dust construction specialised personnel were exposed to were established to be above OSHA PEL. The highest individual concentrations for silica dust was $1.58\text{mg}/\text{m}^3$ which was 96% higher than OSHA PEL of $0.05\text{ mg}/\text{m}^3$. In addition, the AM for silica dust exposure level was $0.228\text{mg}/\text{m}^3$ which was 78% more than OSHA PEL. Moreover, the respirable dust concentrations were established; the highest individual concentration was $23.19\text{mg}/\text{m}^3$ which was 78% higher than OSHA PEL of $5\text{ mg}/\text{m}^3$ while the overall AM for all the job titles for respirable dust was $3.198\text{mg}/\text{m}^3$ which was 36% less than OSHA PEL of $5\text{mg}/\text{m}^3$. Therefore, it was established in this study that silica dust exposure levels in construction industry in Zambia were above OSHA PEL of $0.05\text{mg}/\text{m}^3$.

7.5 Research Implications

The new established information on the silica dust concentrations which were above OSHA PEL opens up to improvement in silica dust and chemical irritants mitigation strategies. Furthermore, the findings on the high levels and period of exposure to chemical irritants, the inadequate controls used for dust and chemical irritants are the red flags to show that proactive measures have to be put in place to address these problems. The research findings will work as a benchmark for improved strategy and policy formation. Additionally, the established framework is targeted at reducing or mitigating exposures to silica dust and chemical irritants thereby safeguarding the workers' health and projects. This will eventually improve the safety and health culture in the construction industry in Zambia. In summary, Government through its agencies and construction stakeholders that desire to reduce silica dust and chemical irritant exposure and improve occupational health and health culture be guided by the findings of this research and the developed integrated preventive framework. Moreover, the findings and recommendations would serve as part of the guide in setting the silica dust exposure levels and the development of the Occupational Health and Safety National Policy in Zambia.

7.6 Research Recommendations

For the effective silica dust reduction and reduction of risk of ill health and, combination of controls should be implemented as suggested by Tente et al. (2022).

Therefore, there is need for improved ways that incorporate all controls in the hierarchy of controls and participation of all construction stakeholders in reduction of silica dust to safeguard workers' health and the possible effects on the projects.

To reduce period of exposure, workers should be encouraged by management to work in shifts whenever possible so that continuous exposure is avoided. This can be done by working half day shifts on the tasks that have high levels of exposures. It is recommended that skilled workers are put on fixed monthly wages to avoid working for longer periods. To reduce levels of exposure, it is recommended that management provide full proper PPE. Emphasis should be on the quality and skilled approved PPE as encouraged by Timmerman (2017). For example, to ensure that chemical irritants do not penetrate through the gloves and subsequent contact with the skin, bricklayers should be given well fitted, chemical resistant polyvinyl chloride (PVC) gloves. Personal hygiene and use of hand cream such as petroleum jelly after work should be encouraged. Washing reduced the continuous contact of chemicals with the skin. The petroleum jelly on the other hand, moisturizes the skin thereby protecting and aiding in the healing of skin wounds. It should be applied after the skin is washed thoroughly.

More importantly, the findings may mean that safety and health guidelines were not enforced effectively on sites. It is recommended that Zambia formulates the National Occupational Safety and Health (NOSH) policy to improve safety and health on sites. At present, Zambia has no NOSH policy. In the short term, it is recommended that workers receive safety and health training before they are employed and given toolbox talks on the hazards associated with their work activities before any work is performed. Several studies have revealed that training on handling hazards and how workers can protect themselves is useful for skin diseases prevention. In addition, it is recommended that skilled workers get the safety and health training in vocational training. This is for them to be aware of the hazards and risks associated with their skills. When they are employed, pre-employment training and the toolbox talks would be as a reminder for them to adhere to good safety and health practices while working. In summary, the recommendations of the research are as follows;

- i. Combination of all the controls should be utilized.

- ii. Shift work should be encouraged to reduce period of exposure to silica dust and chemical irritants.
- iii. Putting workers on fixed monthly wages should be encouraged to reduce period of exposure as the workers choose to work longer hours even in higher exposures to make more money.
- iv. To reduce levels of exposure, management should provide full, quality, recommended and well-fitted PPE for the activity.
- v. Zambia should formulate NOSH policy to give proper occupational safety and health guidelines to address high exposures to silica dust and chemical irritants since the OHS Act of 2010 seems not very effective considering the research findings.
- vi. Continuous training or retraining on the hazard identification, risk assessment and the effects of the hazard on the workers and the project is recommended in vocational training and the projects.
- vii. The ultimate recommended is the developed framework as it incorporates all activities to mitigate exposures to silica dust and chemical irritants from inception to the end of the project or work activity.

7.7 Limitation of the Research

This research was limited to the silica dust, respirable dust and general dust and the construction activities that produce them. In terms of chemical irritants such as wet works, paint, primer, asphalt, tile fix and other chemicals which are used by bricklayers, carpenters, tilers, painters, road construction workers and the labourers of the named skilled in construction. The findings would be generalised to sectors with similar materials and activities that are performed by the mentioned skilled. Since this research was a cross-sectional one, the symptoms were limited to what was observed during data collection.

7.8 Recommendations for Further Research

Further research is recommended to measure silica dust exposures for specific profession and tasks to find out which profession and tasks are more exposed to silica dust in the construction industry in Zambia. More research is recommended on the effects of silica dust and chemical irritants in terms of respirable diseases and skin diseases. This can be done using a longitudinal study so that the symptoms are

observed for a period of time by the use of full respiratory and skin clinical examinations which give real diagnosis of the symptoms and diseases using clinical methods.

REFERENCES

Adsul, B.B., Laad, P.S., Howal, P.V. and Chaturvedi, R.M., 2011. Health Problems Among Migrant Construction Workers: A Unique Public–Private Partnership Project. *Indian Journal of Occupational and Environmental Medicine*, 15(1), pp.29-32. Available at:

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3143513/>. Accessed on 30 July 2021.

Ahmed, H.O. and Abdullah, A.A., 2012. Dust exposure and respiratory symptoms among cement factory workers in the United Arab Emirates. *Industrial Health*, pp.1203250129-1203250129. Available at:

https://www.jstage.jst.go.jp/article/indhealth/advpub/0/advpub_MS1320/_article/-char/ja/. Accessed on 20 September 2021.

Akbar-Khanzadeh, F., Milz, S., Ames, A., Susi, P.P., Bisesi, M., Khuder, S.A. and Akbar-Khanzadeh, M., 2007. Crystalline silica dust and respirable particulate matter during indoor concrete grinding—wet grinding and ventilated grinding compared with uncontrolled conventional grinding. *Journal of Occupational and Environmental Hygiene*, 4(10), pp.770-779. DOI: 10.1080/15459620701569708.

Ali, M., S. Fattach., M. Alam., F. Ahmed., S. Parveen., M. Royesuddin., M. Ahmed., S. Ali. 2010. “Silicosis-A Case Report.” *Faridpur Medical College Journal*, 5(2),69-71.

<https://doi.org/10.3329/fmcj.v5i2.6827>

Alonazi, M., Beloff, N. and White, M., 2019. Exploring determinants of m-government services: A study from the citizens’ perspective in Saudi Arabia. In *2019 Federated Conference on Computer Science and Information Systems (FedCSIS)*, September 1. pp. 627-631. IEEE.

Anderson-Carpenter, Kaston D.; Watson-Thompson, Jomella; Chaney, Lisa; Jones, Marvia (2016). Reducing Binge Drinking in Adolescents through Implementation of the Strategic Prevention Framework. *American Journal of Community Psychology*, 57(1-2), 36–46. doi:10.1002/ajcp.12029

Avnstorp, C., 1992. Cement eczema. An epidemiological intervention study. *Actadermato-venereologica. Supplementum*, 179, pp.1-22.

Bedoya-Marrugo, E.A., Severiche-Sierra, C.A., Sierra-Calderon, D.D., Jaimes-Morales, J., Marrugo-Ligardo, Y.A. and Espinosa-Fuentes, E.A., 2017. Conditions of Work and Dermatitis in Workers Exposed to Chemical Risks by Cement. *International Journal of Applied Engineering Research*, 12(22), pp.12119-12126. Available at:
<http://www.ripublication.com>. Accessed on 15 May 2022.

Behrangi, E., Habib, A., Tanaz H. F., Zahra A., Shooka, E., 2014. An Unusual Skin Lesion in Cement Irritant Contact Dermatitis: A Case Report. *Skin & Stem Cell. J.*

Bello A, Mugford C, Murray A., 2019. Characterization of Occupational exposures to respirable silica and dust in demolition, crushing, and chipping activities. *Ann Work Expo Health*; 63: 34–44.

Bhagia, L.J. and Sadhu, H.G., 2008. Cost–benefit analysis of installing dust control devices in the agate industry, Khambhat (Gujarat). *Indian Journal of Occupational and Environmental Medicine*, 12(3), p.128.

Bhattarai, S., Murarka, R., Mishra, S., Nepal, A. and Joshi, S.K., 2015. Occupational Hand Eczema among Cement users in Nepal. *International Journal of Occupational Safety and Health*, 5(1), pp.11-13. Available at:
<https://www.nepjol.info/index.php/IJOSH/article/view/16629>. Accessed on 20 February 2020.

Bock, M., Schmidt, A., Bruckner, T. and Diepgen, T.L., 2003. Occupational skin disease in the construction industry. *British Journal of Dermatology*, 149(6), pp.1165-1171. Available at:
<https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2133.2003.05748.x>. Accessed on 20 December 2021.

Bofinger C., 2005. Health Tracking Project -The Development of a National Framework for Managing Occupational Illness and Disease in the Australian Minerals Industry, in Naj Aziz and Bob Kininmonth (eds.), Proceedings of the 2005 Coal Operators' Conference, Mining Engineering, University of Wollongong, 18-20 February 2019.<https://ro.uow.edu.au/coal/84>.

Boudigaard, S.H., Hansen, K.K., Kolstad, H., Kromhout, H. and Schlünssen, V., 2022. Determinants of Respirable Quartz Exposure Concentrations Across Occupations in Denmark, 2018. *Annals of Work Exposures and Health*, 66(4), pp.472-480.

Bourke, J., Coulson, I. and English, J., 2009. British Association of Dermatologists Therapy Guidelines and Audit Subcommittee. *Guidelines for the management of contact dermatitis: an update British Journal of Dermatology*, 160(05), pp.946-954. Available at:

DOI 10.1111/j.1365-2133.2009.09106.x. Accessed on 21 June 2021.

Bringula, R.P., Batalla, M.Y.C., Moraga, S.D., Ochengco, L.D.R., Ohagan, K.N. and Lansigan, R.R., 2012. School Choice of Computing Students: A Comparative Perspective from Two Universities. *Creative education*, 3(06), p.1070. Available at: <https://www.scirp.org/html/23583.html>. Accessed on 02 October 2022.

Bryman, A., 2008. *Social Research Methods*. 3rd. Ed. Oxford: Oxford University Press

Carlo, R.V., Sheehy, J., Feng, H.A. and Sieber, W.K., 2010. Laboratory Evaluation to Reduce Respirable Crystalline Silica Dust When Cutting Concrete Roofing Tiles Using a Masonry Saw. *Journal of Occupational and Environmental Hygiene*, 7(4), pp.245-251. Available at: <https://doi.org/10.1080/15459620903579695>. Accessed on 20 December 2021.

Cashman, M.W., Reutemann, P.A. and Ehrlich, A., 2012. Contact Dermatitis in the United States: Epidemiology, Economic Impact, And Workplace

Prevention. *Dermatologic clinics*, 30(1), pp.87-98. Available at: <https://pubmed.ncbi.nlm.nih.gov/22117870/>.

Accessed on 13 April 2021.

Clark, S.C. and Zirwas, M.J., 2009. Management of Occupational Dermatitis. *Dermatologic Clinics*, 27(3), pp.365-383. Available at: <https://pubmed.ncbi.nlm.nih.gov/19580930/>. Accessed on 20 March 2021.

Creswell, J.W., 2014. Research Design: qualitative, quantitative, and mixed methods approaches. 4th. Ed. SAGE Publications, Inc.

Coccia, C.B., Palkowski, G.H., Ntusi, N.A.B., Schweitzer, B. and Motsosi, T., 2016. Dyspnoea: Pathophysiology and a Clinical Approach. *South African Medical Journal*, 106(1), pp.32-3.

Coenraads, P.J., Nater, J.P., Jansen, H.A. and Lantinga, H., 1984. Prevalence of eczema and other dermatoses of the hands and forearms in construction workers in the Netherlands. *Clinical and experimental dermatology*, 9(2), pp.149-158. Available at: <https://academic.oup.com/ced/article/9/2/149/6630904>. Accessed on 10 January 2021.

Cohen, L.; Swift, S. (1999). The spectrum of prevention: developing a comprehensive approach to injury prevention. *Injury Prevention*, 5(3), 203–207. doi:10.1136/ip.5.3.203

Croteau, G.A., Flanagan, M.E., Camp, J.E. and Seixas, N.S., 2004. The efficacy of local exhaust ventilation for controlling dust exposures during concrete surface grinding. *Annals of occupational hygiene*, 48(6), pp.509-518. Available at: <https://doi.org/10.1093/annhyg/meh050>. Accessed on 13 January 2020.

Dahling, J. J and U. A. Librizzi., 2015. Integrating the Theory of Work Adjustment and Attachment Theory to Predict Job Turnover Intentions. *Journal of Career Development*, 42(3), 215-225. Available at: <https://dahling.pages.tcnj.edu/files/2015/09/DAHLIN-LIBRIZZI-2015.pdf>. Accessed on 25 June 2021.

Dawis, R. V., 2005. The Minnesota theory of work adjustment. In S. D. Brown & R. W. Lent (Eds.), *Career Development and Counselling: Putting Theory and Research to Work*. Hoboken, NJ: John Wiley. Available at: <https://career.iresearchnet.com/career-development/minnesota-theory-of-work-adjustment-mtwa/>. Accessed on 20 December 2019.

Dawis, R.V. and Lofquist, L.H., 1984. *A Psychological Theory of Work Adjustment: An Individual-Differences Model and Its Applications*. University of Minnesota press.

De Blasio, F., Virchow, J.C., Polverino, M., Zanasi, A., Behrakis, P.K., Kiliç, G., Balsamo, R., De Danieli, G. and Lanata, L., 2011. Cough management: a practical approach. *Cough*, 7(1), pp.1-12. Available at: <https://coughjournal.biomedcentral.com/articles/10.1186/1745-9974-7-7>. Accessed on 20 August 2021.

Diepgen, T.L. and Kanerva, L., 2006. Occupational skin diseases. *European Journal of Dermatology*, 16(3), pp.324-330.

ENVIS-NIOH., 2010. Occupational Skin Diseases. Newsletter.vol5. N0.2. Apr-Jun. www.envisnioh.org.

Esmail, R.Y. and Sakwari, G.H., 2021. Occupational Skin Diseases among Building Construction Workers in Dar es Salaam, Tanzania. *Annals of Global Health*, 87(1). Available at: <https://www.annalsofglobalhealth.org/articles/10.5334/aogh.3102/>, Accessed on 12 April 2022.

Fellows, R., and Liu, A. (2008). *Research methods for Construction*, Oxford: Blackwell Publishing Ltd.

Flanagan, M.E., Seixas, N., Majar, M., Camp, J. and Morgan, M., 2003. Silica dust exposures during selected construction activities. *AIHA Journal*, 64(3), pp.319-328. <https://pubmed.ncbi.nlm.nih.gov/12809537/>. Accessed on 20 November 2021.

Geier, J., Lessmann, H., Skudlik, C., Ballmer-Weber, B.K., Weisshaar, E., Uter, W. and Schnuch, A., 2017. Occupational contact allergy in bricklayers, tile setters etc.- Current spectrum of sensitization and recent time trends. *Allergologie Select*, 1(2), p.127-140. Available at: DIO: 10.5414/ALX01593E. Allergol Select. Accessed on 20 May 2020.

Gharpure, A., Heim, J.W. and Vander Wal, R.L., 2021. Characterization and Hazard Identification of Respirable Cement and Concrete Dust from Construction Activities. *International journal of environmental research and public health*, 18(19), p.10126. Available at: <https://doi.org/10.3390/ijerph181910126>. Accessed on 04 January 2022.

Gholami, A., Fani, M.J. and Sadeghi, N., 2012. Occupational Exposure Determination to Silica Dust in an Iron-Stone Ore and Comparison with Standard. *International Journal of Collaborative Research on Internal Medicine & Public Health*, 4(6), pp.0-0. Available at: https://www.researchgate.net/figure/Inhalable-dust-level-in-different-mine-sections-mg-m-3-and-comparison-to-standard_tbl1_268383971. Accessed on 10 January 2022.

Gottesfeld, P., Tirima, S., Anka, S.M., Fotso, A. and Nota, M.M., 2019. Reducing lead and silica dust exposures in small-scale mining in northern Nigeria. *Annals of work exposures and health*, 63(1), pp.1-8.

Handa, S., Kaur, I., Gupta, T. and Jindal, R., 2012. Hand eczema: Correlation of morphologic patterns, atopy, contact sensitization and disease severity. *Indian Journal of Dermatology, Venereology and Leprology*, 78(2), pp.153-158. Available at: <https://pubmed.ncbi.nlm.nih.gov/22421645/>. Accessed on 06 March 2020.

Hayumbu, P., Robins, T.G. and Key-Schwartz, R., 2008. Cross-sectional silica exposure measurements at two Zambian copper mines of Nkana and Mufulira. *International journal of environmental research and public health*, 5(2), pp.86-90. Available at:

<https://europepmc.org/article/med/18678921>. Accessed on 12 July 2019.

Hasan, N.H., Said, M.R. and Leman, A.M., 2012. Local Exhaust Ventilation and Application: A. *International Journal of Engineering & Technology IJET-IJENS* Vol:12 No:04. Pp, 39-42. Available at:

<https://files.core.ac.uk/pdf/13518/235640180.pdf>. Accessed on 28 January 2022.

Health and Safety Executive (HSE)., 2020. EH40/2005 Workplace exposure limits. 4th edition. London: TSO. Available at:

<https://www.hse.gov.uk/pubns/priced/eh40.pdf>. Accessed on 25 March 2022.

Health and Safety Executive (HSE)., 2014. General Methods for Sampling and Gravimetric Analysis of Respirable, Thoracic and Inhalable Aerosols (MDHS14/4). Available at: <http://www.hse.gov.uk/pubns/mdhs/index.htm>. Accessed on 25 March 2022.

Health and Safety Executive., 2012. On-tool Control to Reduce Exposure to Respirable Dust in the Construction Industry. Available at: <https://www.hse.gov.uk/research/rrpdf/rr926.pdf>. Accessed on 20 December 2021.

HSE, 2005. General Methods for Determination of Hazardous Substances- Crystalline Silica in Respirable Airborne Dusts (MDHS101/2). Available at: <http://www.hse.gov.uk/pubns/mdhs/index.htm>. Accessed on 25 March 2022.

Howie, R.M., 2005. Respiratory Protective Equipment. *Occupational and Environmental Medicine*, 62(6), pp.423-428. Available at:

<https://oem.bmj.com/content/62/6/423>. Accessed on 20 October 2022.

International Labour Organisation-ILO., 2012. Zambia Country Profile on Occupational Safety and Health 2012. Lusaka Zambia. Available at:

<https://silo.tips/downloads/zambia-country-profile-on-occupational-safety-and-health-2012>. Accessed on 28 August 2019.

Institute of Occupational Medicine (IOM)., 2011. SHEcan report: health, socio-economic and environmental aspects of possible amendments to the EU Directives on the protection of workers from the risks related to the exposure to carcinogens and mutagens at work. Respirable crystalline silica. SHEcan P 937/8.

Available at <http://www.occupationalcancer.eu/projresults.html>. Accessed 30 June 2021.

Institution of Occupational Safety and Health., 2014. Construction Dust-An Industry Survey.

Iraji, F., Asilian, A., Enshaieh, S., Shamoradi, Z. and Faghihi, G., 2006. Contact dermatitis in cement workers in Isfahan. *Indian Journal of Dermatology*, 51(1), p.30. Available from: <http://www.e-ijd.org/text.asp?2006/51/1/30/25185>. Accessed on 19 September 2019.

Johnson, G. C., 2004. Reconceptualising the visual in narrative inquiry into teaching. *Teaching & Teacher Education*, 20(5), 423-434.

Joshi, A., Kale, S., Chandel, S. and Pal, D.K., 2015. Likert scale: Explored and Explained. *British Journal of Applied Science & Technology*, 7(4), p.396. Available at:

<https://eclass.aspete.gr/modules/document/file.php/EPPAIK269/5a7cc366dd963113c6923ac4a73c3286ab22.pdf>. Accessed on 02 September 2022.

Kim, T.S., Kim, H.A., Heo, Y., Park, Y., Park, C.Y. and Roh, Y.M., 2002. Level of Silica in the Respirable Dust Inhaled by Dental Technicians with Demonstration of Respirable Symptoms. *Industrial Health*, 40(3), pp.260-265. Available at:

https://www.jstage.jst.go.jp/article/indhealth1963/40/3/40_3_260/_article.

Accessed on 20 January 2022.

Kirkeskov, L., Hanskov, D.J.A. and Brauer, C., 2016. Total and respirable dust exposures among carpenters and demolition workers during indoor work in Denmark. *Journal of Occupational Medicine and Toxicology*, 11(1), pp.1-8. DOI 10.1186/s12995-016-0134-5. Accessed on 20 June 2021.

Kreff, S., Wolff, J. and Rose, C., 2020. Silicosis: an update and guide for clinicians. *Clinics in Chest Medicine*, 41(4), pp.709-722.

Lalonde, D., Joukhadar, N. and Janis, J., 2019. Simple Effective Ways to Care for Skin Wounds and Incisions. *Plastic and Reconstructive Surgery Global Open*, 7(10). Available at: DIO: 10.1097/GOX.0000000000002471. Accessed on 01 January 2022.

Li, C.Z., Zhao, Y. and Xu, X., 2019. Investigation of Dust Exposure and Control Practices in the Construction Industry: Implications for Cleaner Production. *Journal of Cleaner Production*, 227, pp.810-824. Available at:
DOI: <https://doi.org/10.1016/j.jclepro.2019.04.174>. Accessed on 07 September 2021.

Lim, Y.L. and Goon, A., 2007. Occupational skin diseases in Singapore 2003–2004: an epidemiologic update. *Contact dermatitis*, 56(3), pp.157-159. Available at:
<https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1600-0536.2007.01032.x>.
Accessed on 10 December 2021.

Lumens, M.E. and Spee, T., 2001. Determinants of exposure to respirable quartz dust in the construction industry. *Annals of occupational hygiene*, 45(7), pp.585-595. Available at:
<https://academic.oup.com/annweh/article-pdf/45/7/585/455519/45-7-585.pdf>.
Accessed on 05 October 2019.

Lushniak, B.D., 2004. Occupational contact dermatitis. *Dermatologic therapy*, 17(3), pp.272-277. Available at: <https://doi.org/10.1111/j.1396-0296.2004.04032.x>. Accessed on 20 May 2021.

Martínez-Mesa, J., González-Chica, D.A., Duquia, R.P., Bonamigo, R.R. and Bastos, J.L., 2016. Sampling: how to select participants in my research study? *Anais brasileiros de dermatologia*, 91, pp.326-330.

Maxwell, J.A., 2012. *Qualitative research design: An interactive approach*. Sage publications.

McQueen, P. and McQueen, H., 2010. *Key Concepts in Philosophy* Basingstoke: Palgrave MacMillan.

Meding, B. and Swanbeck, G., 1990. Consequences of having hand eczema. *Contact dermatitis*, 23(1), pp.6-14. Available at: <https://pubmed.ncbi.nlm.nih.gov/2144814/>. Accessed on 14 February 2021.

Miles, M.B., Huberman, A.M. and Saldaña, J., 2014. *Qualitative data analysis: A methods sourcebook*. Sage publications.

Mir, M.M., Mir, M.S., Mir, N. and Mir, S.M., 2017. Occupational Skin Diseases in Construction Workers at a Large Construction Site. *European Journal of Pharmaceutical and Medical Research*, 4(12), pp. 383-385. Available at: <http://www.wjpmr.com/download/article/29112017/1511956966.pdf>. Accessed on 15 February 2022.

Mohamed, S.H., El-Ansary, A.L. and Abd El-Aziz, E.M., 2018. Determination of crystalline silica in respirable dust upon occupational exposure for Egyptian workers. *Industrial health*, 56(3), pp.255-263. Available at: <https://www.semanticscholar.org/paper/Determination-of-crystalline-silica-in-respirable-Mohamed-El-Ansary/1ffc780cc4b8b6f21c6ebf30166c52870ed5996>. Accessed on 19 June 2021.

Moser, H.A., 1992. Dust hazards in building construction works. Staubgefahr bei Arbeiten im Hochbau. *Staub, Reinhaltung der Luft*; (Germany), 52(4).

Motshelanoka, L.M., 2005. National programme for the elimination of silicosis in South Africa. *Occupational Health Southern Africa*. IOHA.

Mwanaumo, E., Thwala, W.D., Pretorius, JH., 2014. Assessing Health and Safety Requirements in Construction Contracts in Botswana. *Journal of Economics and Behavioural Studies*, 6 (1), 37-43.

Mwanaumo, E., 2012. An Integrated Approach to Stakeholder Intervention in Construction Health and Safety. PhD Thesis, University of Johannesburg.

National Institute for Occupational Safety and Health. Preventing Silicosis and Deaths in Construction Workers. Atlanta, GA: Centers for Disease Control and Prevention., 2014. Accessed on 01 February 2019.

National Institute for Occupational Safety and Health. Silica, Crystalline (as respirable dust), NIOSH Pocket Guide to Chemical Hazards. Atlanta, GA: Centers for Disease Control and Prevention., 2010. Accessed on 01 February 2019.

National Toxicology Program. Silica, Crystalline (Respirable Size), Report on Carcinogens, Fourteenth Edition. Triangle Park, NC: National Institute of Environmental Health and Safety., 2016. Accessed on 01 February 2019.

Normohammadi, M., Kakooei, H., Omid, L., Yari, S. and Alimi, R., 2016. Risk Assessment of Exposure to Silica Dust in Building Demolition Sites. *Safety and Health at Work*, 7(3), pp.251-255.

Nij, E.T., Hilhorst.S., Spee. T., Spierings. J., Steffens. F., Lumens. M., Heederik. D., 2003. Dust Control Measures in the Construction Industry. *Annals of Occupational Hygiene*, 47(3): p. 211-218. Available at: <https://doi.org/10.1093/annhyg/meg023>.

Nij, E.T., Borm, P., Höhr, D. and Heederik, D., 2002. Pneumoconiosis and Exposure to Quartz-Containing Dust in the Construction Industry. *Annals of Occupational Hygiene*, 46(suppl_1), pp.71-76.

Nirmala, C.J. and Prasad, S.D., 2019. Occupational hazards and public health concerns of migrant construction workers: an epidemiological study in southern

India. *International journal of community medicine and public health (Gujarat)*, 6(2), pp.818-822.

DOI: <http://dx.doi.org/10.18203/2394-6040.ijcmph20190214>. Accessed on 20 June 2021.

Nsunge N., 2019. An Assessment of Dust Exposure Levels and Factors Associated with the Occurrence of Respiratory Symptoms Among Workers in the Road Construction Industry in Lusaka, Zambia. Masters Dissertation, University of Zambia.

Occupational Health and Safety Act (OHS)., 2010. Available at: <https://www.parliament.gov.zm/node/3409>. Accessed on 20 May 2020.

Occupational Safety and Health Administration (OSHA)., 2017. OSHA Fact Sheet: OSHA's Respirable Crystalline Silica Standards for Construction. Available at: <https://www.osha.gov/Publications/OSHA3681.pdf>. Accessed on December 8 2020.

Occupational Safety and Health Administration (OSHA)., 2002. OSHA Fact Sheet: Crystalline Silica Exposure Health Hazard Information. Washington, DC: U.S. Department of Labour. https://www.osha.gov/oshadoc/data_general_facts/crystalline-factsheet.pdf. Accessed 01 February 2019.

Peters, S., Vermeulen, R., Portengen, L., Olsson, A., Kendzia, B., Vincent, R., Savary, B., Lavoué, J., Cavallo, D., Cattaneo, A. and Mirabelli, D., 2011. Modelling of occupational respirable crystalline silica exposure for quantitative exposure assessment in community-based case-control studies. *Journal of Environmental Monitoring*, 13(11), pp.3262-3268.

Ugbogu, O.C., Ohakwe, J. and Foltescu, V., 2009. Occurrence of Respiratory and Skin Problems Among Manual Stone-Quarrying Workers. *African Journal of Respiratory Medicine*, 2009, pp.23-26. Available at:

<https://www.africanjournalofrespiratorymedicine.com/articles/occurrence-of-respiratory-and-skin-problems-among-manual-stonequarrying-workers.pdf>.

Accessed on 10 June 2021.

Quandt, S.A., Newman, J.C., Pichardo-Geisinger, R., Mora, D.C., Chen, H., Feldman, S.R. and Arcury, T.A., 2014. Self-Reported Skin Symptoms and Skin-Related Quality of Life Among Latino Immigrant Poultry Processing and Other Manual Workers. *American journal of industrial medicine*, 57(5), pp.605-614. Available at: <https://doi.org/10.1002/ajim.22291>. Accessed on 10 March 2019.

Raanan, R., Zack, O., Ruben, M., Perluk, I. and Moshe, S., 2022. Occupational Silica Exposure and Dose–Response for Related Disorders—Silicosis, Pulmonary TB, AIDs and Renal Diseases: Results of a 15-Year Israeli Surveillance. *International Journal of Environmental Research and Public Health*, 19(22), p.15010.

Radnoff, D.L. and Kutz, M.K., 2014. Exposure to crystalline silica in abrasive blasting operations where silica and non-silica abrasives are used. *Annals of occupational hygiene*, 58(1), pp.19-27. Available at: <https://academic.oup.com/annweh/article/58/1/19/141880>. Accessed on 10 March 2019.

Raynor, P.C. and Peters, T.M., 2016. Controlling Nanoparticle Exposures. In *Assessing Nanoparticle Risks to Human Health*. pp. 153-177. William Andrew Publishing. Available at: DOI 10.1016/B978-0-323-35323-6.00007-4. Accessed on 20 January 2022.

Riala, R., 1988. Dust and quartz exposure of Finnish construction site cleaners. *The Annals of occupational hygiene*, 32(2), pp.215-220. Available at: <https://www.irsst.qc.ca/media/documents/pubirsst/r-771.pdf>. Accessed on 14 July 2019.

Road Development Agency., 2015. RDA 20 Percent Mandatory Sub-contracting Guidelines. 2nd Issue. Available at: <http://www.rda.org.zm/?wpdmcategory=rehabilitation-works>. Accessed on 29 June 2019.

Rönmark, E.P., Ekerljung, L., Lötvall, J., Wennergren, G., Rönmark, E., Toren, K. and Lundbäck, B., 2012. Eczema among adults: prevalence, risk factors and relation to airway diseases. Results from a large-scale population survey in Sweden. *British Journal of Dermatology*, 166(6), pp.1301-1308. Available at:
DOI: 10.1111/j.1365-2133.2012.10904.x. Accessed on 10 September 2021.

Saji, K.G., Zubair, M., Nair, S.B. and Varghese, P.R., 2018. An epidemiological study on effect of occupational exposure of cement. *International Journal of Community Medicine and Public Health*, 5(5), pp.5105-9.
DOI: <http://dx.doi.org/10.18203/2394-6040.ijcmph20184734> accessed on 11 February 2022.

Saunders M. N. K. Lewis P. and Thornhill A., 2000. *Research Methods for Business Students*. 2nd ed. Financial Times/Prentice Hall.

Saunders, M., Lewis, P. and Thornhill, A. 2007. *Research Methods for Business Students*. 4th Edition, Financial Times Prentice Hall, Edinburgh Gate, Harlow.

Sabet, P. G.P., Aadal, H., Jamshidi, M. H.M. and Rad, K G., 2013. Application of Domino Theory to Justify and Prevent Accident Occurrence in Construction Sites. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)* e-ISSN: 2278-1684, p-ISSN: 2320-334X, 6 (2), PP 72-76. Available at:
<https://doi.org/10.9790/1684-0627276>. Accessed on 20 January 2021.

Sharma, V., Mahajan, V.K., Mehta, K.S. and Chauhan, P.S., 2014. Occupational contact dermatitis among construction workers: Results of a pilot study. *Indian Journal of Dermatology, Venereology and Leprology*, 80, p.159. Available at:
<https://pubmed.ncbi.nlm.nih.gov/24685859/>. Accessed on 11 March 2020.

Shah, K.R., and Tiwari, R.R., 2010. Occupational Skin Problems in Construction Workers. *Indian J Dermatol*. Oct-Dec; 55(4): 348–351. doi: 10.4103/0019-5154.74537. Available at: <https://www.e-ijd.org/text.asp?2010/55/4/348/74537>. Accessed on 24 August 2019.

Shahreza, H.D. and Razavizadeh, N., 1999. Determination and Evaluation of Free Silica in The Respiratory Zone of Glassworkers with X-Ray Diffraction Method. *Iranian Journal of Public Health*, 28(1-4), pp.121-132. Available at:

<https://ijph.tums.ac.ir/index.php/ijph/article/view/1731>. Accessed on 23 January 2020.

Scotland, J., 2012. Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. *English language teaching*, 5(9), pp.9-16. Available at:

<https://files.eric.ed.gov/fulltext/EJ1080001.pdf>. Accessed on 15 September 2019.

Skoet, R., Olsen, J., Mathiesen, B., Iversen, L., Johansen, J.D. and Agner, T., 2004. A survey of occupational hand eczema in Denmark. *Contact dermatitis*, 51(4), pp.159-166. Available at: <https://pubmed.ncbi.nlm.nih.gov/15500664/>. Accessed on 29 April 2020.

Spoof, J. and Elsner, P., 2001. Cement Burns: A Review 1960–2000. *Contact Dermatitis*, 45(2), pp.68-71. Available at:

<https://onlinelibrary.wiley.com/doi/full/10.1034/j.1600-0536.2001.045002068.x>.

Accessed on 10 November 2019.

Swanepoel, A.J., 2012. Exposure to Respirable Crystalline Silica in Central South African Farm Workers. Doctoral dissertation, University of the Witwatersrand, Faculty of Health Sciences.

Tente P., Mwanaumo, E., Thwala, W D. 2022. Effectiveness of Controls for Respirable Crystalline Silica Dust Exposure in Construction: A Literature Review. Proceedings of the Construction Industry Development Board 12TH Postgraduate Conference. Building Innovation and Sustainable Construction Practices. 22 -24 June 2022. International Convention Centre, Cape Town, South Africa.

https://www.researchgate.net/publication/363107844_Effectiveness_of_controls_for_respirable_crystalline_silica_dust_exposure_in_construction_A_literature_review.

Tente P and Mwanaumo E. 2022. Levels and Period of Exposure to Chemical Irritants in relation to symptoms of skin diseases for Construction Specialised Personnel in Zambia. *Proceedings of the Construction Business and Project Management Conference*. Building Innovation and Sustainable Construction Practices. 10 -12 July 2022. East London, South Africa.

Tente P., 2016. Safety and Health in the construction Industry in Zambia. Masters Dissertation, University of Zambia.

Tente, P and Muya, M., 2014. Safety and Health in Zambia's Construction Industry: Way forward. In: *EIZ Annual Symposium: Emerging Technologies and Innovations for Value Addition in Africa*. 18-19 April 2014, Zambezi Sun Hotel, Livingstone, Zambia.

Timmerman, J., 2017. Contact Dermatitis in the Construction Industry. PhD Thesis, Utrecht University.

Timmerman, J.G., Heederik, D., Spee, T. and Smit, L.A., 2014. Skin Symptoms in The Construction Industry: Occurrence and Determinants. *American journal of industrial medicine*, 57(6), pp.660-668.

Thomas, C.R. and Kelley, T.R., 2010. A brief review of silicosis in the United States. *Environmental health insights*, 4, pp.EHI-S4628.

Thorpe, A., Ritchie, A.S., Gibson, M.J. and Brown, R.C., 1999. Measurements of The Effectiveness of Dust Control On Cut-Off Saws Used in the Construction Industry. *Annals of Occupational Hygiene*, 43(7), pp.443-456. Available at: <https://academic.oup.com/annweh/article-abstract/43/7/443/167805>. Accessed on 24 February 2020.

Valiante, D.J., Schill, D.P., Rosenman, K.D. and Socie, E., 2004. Highway repair: A New Silicosis Threat. *American journal of public health*, 94(5), pp.876-880. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1448352/>. Accessed on 30 June 2020.

Verhoeven, E.W.M., Kraaimaat, F.W., Van De Kerkhof, P.C.M., Van Weel, C., Duller, P., Van Der Valk, P.G.M., Van Den Hoogen, H.J.M., Bor, J.H.J., Schers, H.J. and Evers, A.W.M., 2007. Prevalence of Physical Symptoms of Itch, Pain and Fatigue in Patients with Skin Diseases in General Practice. *British Journal of Dermatology*, 156(6), pp.1346-1349.

Vij, S. and Farooq, R., 2017. Moderating variables in business research. *The IUP Journal of Business Strategy*, 14(4), pp.34-54. Available at: https://www.researchgate.net/publication/322930562_Moderating_Variables_in_Business_Research. Accessed on 11 September 2022.

Wiebert, P., Lönn, M., Fremling, K., Feychting, M., Sjögren, B., Nise, G., Kauppinen, T., Plato, N. and Gustavsson, P., 2012. Occupational exposure to particles and incidence of acute myocardial infarction and other ischaemic heart disease. *Occupational and environmental medicine*, 69(9), pp.651-657. Available at: <https://pubmed.ncbi.nlm.nih.gov/22693266/>. Accessed on 23 March 2020.

Wu, Z., Zhang, X. and Wu, M., 2016. Mitigating construction dust pollution: State of the art and the way forward. *Journal of cleaner production*, 112, pp.1658-1666. Available at: https://www.researchgate.net/publication/353840401_Mitigating_Dust_Pollution_from_Construction_Activities_A_Behavioural_Control_Perspective. Accessed on 20 May 2022.

Yassin, A., Yebesi, F. and Tingle, R., 2005. Occupational Exposure to Crystalline Silica Dust in the United States, 1988–2003. *Environmental health perspectives*, 113(3), pp.255-260. Available at: <https://www.jstor.org/stable/3436036>. Accessed on 09 April 2020.

APPENDICES

A1: Questionnaire Survey Cover Letter



THE UNIVERSITY OF ZAMBIA

School of Engineering Dept of Civil & Environmental Engineering

P.O Box 32379, Lusaka.

Cell: 0977344275, E-mail: pmtente@yahoo.co.uk

March, 2021

Dear Sir / Madam,

**QUESTIONNAIRE SURVEY ON AN INTEGRATED PREVENTIVE
FRAMEWORK FOR CONSTRUCTION SITE PERSONNEL EXPOSED TO
SILICA DUST AND CHEMICAL IRRITANTS IN ZAMBIA**

I am a student at The University of Zambia, pursuing a Doctor of Philosophy in Construction Management. The topic of my research is "An integrated preventive framework for construction personnel exposed to silica dust and chemical irritants in Zambia.". The aim of the study is to establish an integrated preventive framework that can be used to reduce exposure to silica dust and chemical irritants for construction site personnel in Zambia. This survey research results will help to come up with an integrated preventive framework to help reduce exposure to silica dust and chemical irritants in Zambia.

Kindly spare some time to answer the questionnaire based on your experience in the construction industry. All the information that will be collected will be strictly confidential and will only be used for research purposes. For any enquiries, please do not hesitate to communicate to the undersigned using the address provided above. Thank you for your cooperation.

Yours Faithfully,

Prisca Tente (PhD Student)

A2: QUESTIONNAIRE

The purpose of this research is to get information that will help to establish an integrated preventive framework to reduce exposure to silica dust and chemical irritants for construction site personnel in Zambia. The questionnaire data will feed in the other data that will be done using dust measuring instruments, observations and photographs. The research is limited to specialised workers who are exposed to silica dust and chemical irritants on a road and building construction sites.

Kindly note: All information provided will be strictly confidential. Please TICK (✓) your answer which is applicable to you.

SECTION A: BACKGROUND INFORMATION

1. What is your gender?

- (a) Male 1 (b) Female 2

2. Which age group do you belong to?

- (a) ≤ 25 yrs 1 (b) $26 \leq 35$ yrs 2 (c) $36 \leq 45$ yrs 3 (d) $46 \leq 55$ yrs 4
(e) > 55 yrs 5

3. Which type of construction are you involved in?

- (a) Road Construction 1 (b) Building Construction 2

4. What is your job title?

- (a) Carpenter 1 (b) Bricklayer 2 (c) Painter 3 (d) Batcher 4
(e) Handyman/Labourer 5 (f) Tiler 6 (g) Demolition Worker 7
(h) Road construction worker 8

5. How many years have you worked on this job title in the construction industry?

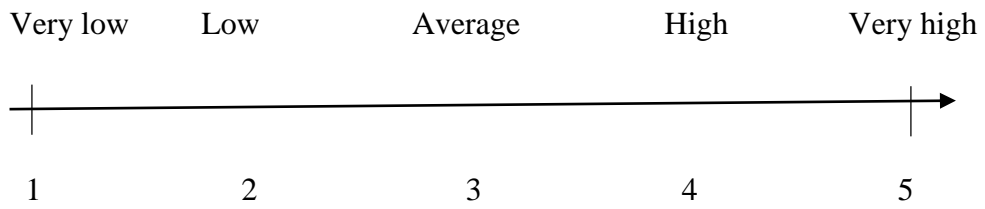
- (a) $3 \leq 5$ years 1 (b) $6 \leq 10$ years 2 (c) > 10 years 3

SECTION B: SILICA DUST

6. Do you experience nuisance from dust during working on construction site?

- (a) Yes 1 (b) No 2

7. What level of dust are you exposed to while working on construction site? On the 5 points Likert scale where 1 means very low, 2 is low, 3 is average, 4 is high and 5 means very high, choose according to your exposure level.



8. What do you use on site to protect yourself and others from dust exposures?

- (a) Dust suppression using water only 1 (b) Water and LEV 2
- (c) Local Exhaust Ventilation (LEV) either on the machine or in the room only 3
- (d) Respiratory Protective Equipment (Dust masks) only 4 Water, LEV and dust masks 5
- (f) Respirators and water 6 (g) None of the above / Not applicable 7

9. What other dust suppression or control do you think can work to reduce dust on sites? Or how best do you think can help protect workers from suffering from respiratory diseases in the construction industry?

.....

.....

.....

.....

.....

.....

.....

.....

10. Do you think the dust suppression or control measures used on site effectively protect you from dust exposure and prevent respiratory diseases?

- (a) Yes 1 (b) No 2

11. How often do you wear dust masks while working?

- (a) Always 1 (b) Sometimes 2 (c) I don't wear 3
- (d) Whenever I am working where there is dust 4

12. Why do you wear a dust mask?

- (a) I want to protect myself so I do not get respiratory diseases
- (b) My supervisor/Safety Officer ensures that I wear (c) They are not provided
- (d) They provide poor quality dust masks; it is as good as not wearing
- (e) Dust masks disturb my work/ I do not feel comfortable
- (f) I do not wear

13. If you wear dust masks during work, what type of dust masks do you usually wear?

- (a) Disposable dust masks (b) Industrial dust masks (half face)
- (c) Disposable (N95) (d) Face masks because it mandatory in corona virus times
- (e) I do not wear

14. Do you experience respiratory symptoms such as coughing, wheezing, shortness of breath because of exposure to dust?

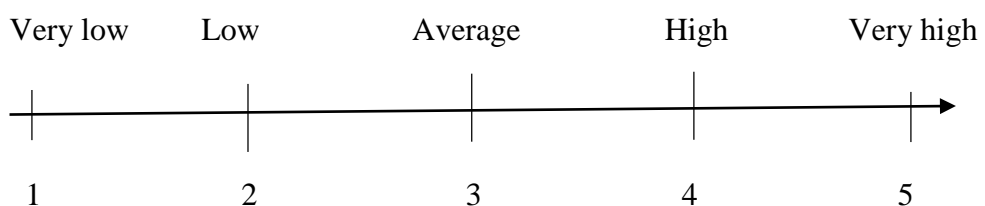
- (a) Coughing (b) Wheezing (c) Shortness of breath (d) N

SECTION C: CHEMICAL IRRITANTS

15. Do you experience exposure to chemical irritants such as cement, wet concrete, epoxy resins, paint, grout or wet tile fix/filler, used oil, bitumen while working on construction site?

- (a) Yes (b) No

16. What level of chemical irritants are you exposed to while working on site? On the 5 points Likert scale where 1 means very low, 2 is low, 3 is average, 4 is high and 5 means very high, choose according to your exposure level.



17. How long are you exposed to chemical irritants in a day during work?

- (a) < 2 hours (b) $3 \leq 8$ hours (c) > 8 hours

18. Did you have one of the following symptoms on your hands or fingers while working on construction site?

- (a) Itchy hands or fingers with fissures (b) Scaly hands or fingers
(c) Vesicles on the hands or between the fingers
(d) Red bumps on hands or fingers
(e) Swollen hands or fingers (g) None of the above

19. If you experienced any of the above skin symptoms, how long did they last?

- (a) < 3 weeks (b) $1 \leq 3$ Months (c) $3 \leq 6$ Months (d) > 6 Months

20. How many times have you experienced the skin symptoms?

- (a) Once (1) (b) Twice (2) (c) Three times (3) (d) > 3 times

21. When you experienced the skin symptoms, what happened?

- (a) I was given light work or was given another task which does not require me to be exposed to chemical irritants (b) I just ignored them
continued working as usual
(c) I had to seek medical attention (I went to the clinic or I took medication)
(d) I was given some days off

22. How dirty are your hands at the end of a working day?

- (a) Very dirty (more than half of your skin surface is dirty) (b) A bit dirty
(c) Not dirty

23. How often do you wear gloves while working?

- (a) Always (b) Sometimes (c) I don't wear gloves

24. Why do you wear gloves while working?

- (a) I want to protect myself so I do not get skin diseases
(b) My supervisor/Safety Officer ensures that I wear gloves

- (c) Gloves are not provided
- (d) Gloves disturb my work/ I do not feel comfortable
- (e) I do not wear

25. If you use gloves during the work, what type of gloves do you usually use?

- (a) Disposable gloves (b) Latex housekeeping gloves (c) Cotton
gloves
- (d) Leather gloves (e) I do not wear

26. Do you wear gumboots and long-sleeved overalls when working with wet cement/concrete?

- (a) Yes (b) No

27. Are there adequate washing facilities available on site to wash off contaminants/dirty after work?

- (a) Yes (b) No

28. How often do you wash your hands / feet after work?

- (a) I wash daily at work (b) I wash daily at home
- (b) (c) I wash sometimes at work
- (d) I wash several times depending on how dirty my hands are

29. How often do you use/apply hand cream or Vaseline before working or after washing your hands?

- (a) Once a day (b) Every other day (c) Once a week
- (d) Once in a while (e) I have not used it

30. What other ways do you think would help prevent chemical irritants from coming in to contact with the skin while working on sites? or how best do you think will help protect workers from skin diseases in construction industry?

.....

.....
.....

THANK YOU

A3:Observation Schedule

Key Issues	Description of observed
Dust exposure levels	<ul style="list-style-type: none"> • Heaps along the road • Dust environment • Dusty activities
Chemical irritants exposure levels	<ul style="list-style-type: none"> • How workers handled chemicals • The messy PPE and surroundings
Period of exposure to dust	<ul style="list-style-type: none"> • Time of start task to end task
Period of exposure to chemical irritants	<ul style="list-style-type: none"> • Time to start task to end task
Prevalence of symptoms of respiratory diseases	<ul style="list-style-type: none"> • Coughing • Wheezing • Shortness of breath
Prevalence of symptoms of skin diseases	<ul style="list-style-type: none"> • Scaly hands • Red bumps • Vesicles • Hands with fissures
Controls for dust	<ul style="list-style-type: none"> • Water suppression • Respirators • Goggles •
Controls for chemical irritants	<ul style="list-style-type: none"> • Gloves • Worksuits • Gumboots

A4: Framework Validation Questionnaire Cover Letter



THE UNIVERSITY OF ZAMBIA

School of Engineering Dept of Civil & Environmental Engineering

P.O Box 32379, Lusaka.

Cell: 0977344275, E-mail: pmtente@yahoo.co.uk

August, 2022

Dear Sir / Madam,

**QUESTIONNAIRE SURVEY ON VALIDATION OF AN INTEGRATED
PREVENTIVE FRAMEWORK FOR CONSTRUCTION SITE
PERSONNEL EXPOSED TO SILICA DUST AND CHEMICAL
IRRITANTS IN ZAMBIA**

I am a student pursuing a Doctor of Philosophy in Construction Management at The University of Zambia. My research topic is an integrated preventive framework for construction personnel exposed to silica dust and chemical irritants in Zambia. As the research comes to the close, the preventive framework was established based on the research findings.

Kindly help with validation of the framework by answering attached questionnaire. The purpose of this validation is to check the functionality, validity and the model. The purpose of the validation is to

Thank you in anticipation for your time and warm cooperation.

Yours Faithfully,

Prisca Tente (PhD Student)

A5: Validation Questionnaire

Kindly answer the following questions based on your expertise. Please, TICK (✓) in the box for **section A**, and in **section B** and **C**, place a number of your choice in the space provided. The questions have five options ranging from **1 to 5**, where **Strongly Disagree is 1, Disagree is 2, Not Sure is 3, Agree is 4** and **Strongly Agree is 5**. **Note:** For lung function, ratio of **FEV1/FVC ≥ 70% will be considered normal if it is greater than or equal to 70%**, where FEV1= Force Expiratory Volume in one second and FVC= Forced Vital Capacity. OHSI=Occupational Health Safety Institute. Table 1 shows the involvement of construction stakeholders at each stage.

Section A

1. What is your gender?

(a) Male (b) Female

2. What type of construction stakeholder group do you belong to?

(a) Client Project Manager Engineers
 (b) (d) Contractors
 (e) Health & Safety Agent/specialist (d) Government agency

Section B –Based on the Model in Figure 1

Preliminary Prevention Stage	
3	Conducting medical examination for lung function and skin before employing workers will help detect the symptoms early thereby encouraging the workers' health.
4	Induction and training of project team on their responsibilities, health & safety plan, current health & safety legal frameworks and exposure control plan will help them to know the dangers and how to protect themselves from silica dust and chemical irritant hazards.
Enforcement Prevention Stage	
5	Practically taking the workers through the use of tools, control methods will help them know how to reduce exposure to silica dust and chemical irritants.
6	Showing workers how to conduct tool box talks and risk assessment will help them to adhere to health and safe practices towards reduction of exposure to silica dust and chemical irritants.

Execution Prevention Stage	
7	Ensuring that workers perform their work activities according to the recommended control methods and tools will help reduce exposure and review exposure control plan and methods.
8	Practicing personal hygiene and housekeeping will reduce the period of exposure to dust and chemicals thereby protecting the workers from further exposure.
Process duration	
9	Conducting tool box talks and risk assessment daily (red arrow cycle in the model) before any work activity will help encourage good health and safety practice.
10	Repeating the sub-stages 3 (health and safety methods) to 6 (post work activity) quarterly (every after three months) will help revise or amend the controls on how effective they have been in the last three months. Note: Blue arrow cycle in the model.
11	Repeating the sub-stages 1 (medical examination) to 6 (post work activity) biannually (every after six months) will help establish how effective the preventive controls have been in reducing exposure to silica dust and chemical irritants in regard to safeguarding the workers' health. Note: Green arrow cycle- complete cycle in the model.

Section C

Model Assessment	
12	The control methods in the model can help reduce exposure to silica dust and chemical irritants.
13	The model has integrated aspects that may work well to reduce silica dust and chemical irritants.
14	The approaches in the model on silica dust and chemical irritant controls are familiar.
15	The model is easy to understand and follow.
15	The preventive sub-stages in the model can improve silica dust and chemical irritants controls.
17	The relationship among the sub-stages are clear.
18	The proper use of the model could help reduce exposure to silica dust and chemical irritants.
19	Proper use of the model could improve overall health and safety culture of construction stakeholders.

20. What is your overall score for the model?

- a) Very Bad b) Bad c) Fair d) Good e) Very Good

Kindly give comments on how the model can be improved

.....

.....

.....

.....

Thank you!!

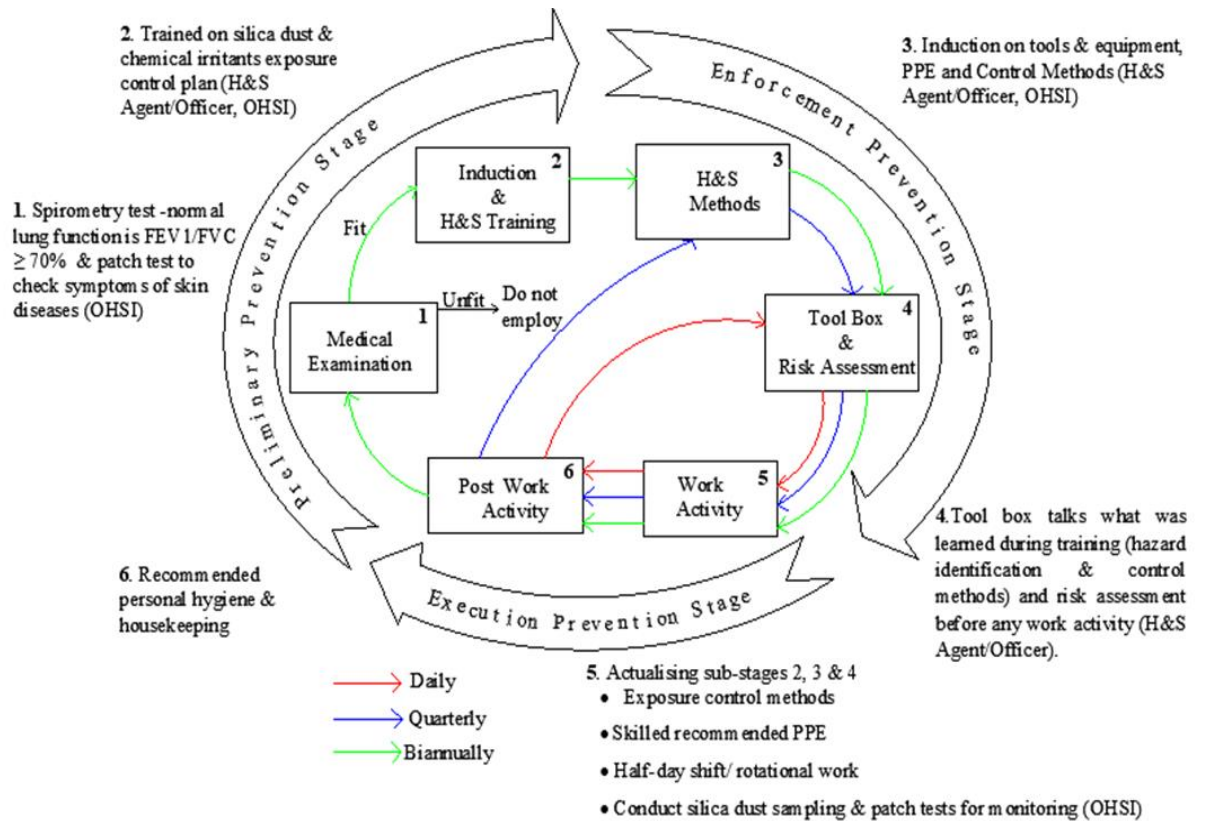


Figure 1: Preventive Framework Model

Table 1: Construction Stakeholder Involvement in the Preventive Framework

Construction Stakeholders	Preliminary Preventive Stage		Enforcement Preventive Stage		Execution Preventive Stage	
	Medical Examination	Induction & Training	H & S Methods	Toolbox & Risk Assessment	Work Activity	Post Work Activity
Client	√	√	√	√	√	√
Project Manager	√	√	√	√	√	√
Engineers	√	√	√	√	√	√
Architects Designers	√	√	√	√	√	√
Consulting Engineers	√	√	√	√	√	√
Civil Engineers	√	√	√	√	√	√
Electrical Engineers	√	√	√	√	√	√
Mechanical Engineers	√	√	√	√	√	√
Health & Safety Agent	√	√	√	√	√	√
Main Contractor	√	√	√	√	√	√
Subcontractors	√	√	√	√	√	√
Suppliers	√	√	√	√	√	√
Government Agencies	√	√	√	√	√	√
Health & Safety Officer	√	√	√	√	√	√
Health & Safety Committee	√	√	√	√	√	√
Skilled & Other Personnel	√	√	√	√	√	√
Community Representatives	√	√	√	√	√	√