FACILITATORS AND BARRIERS INFLUENCING IMPLEMENTATION OF INTERVENTIONS TO ELIMINATE SILICOSIS IN THE SOUTH AFRICAN MINING INDUSTRY

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DECLARATION

I hereby declare that this research report is my own, unaided work. It is being submitted for the degree, Master of Science in Epidemiology in the field of Implementation Science at the University of the Witwatersrand, Johannesburg. The contents of this research report are original and have not been submitted for any other degree or qualification in this, or any other university.

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ABSTRACT

Background

Silicosis is an occupational disease that affects workers, their life, livelihoods, families and communities. Poor workers' health and wellness impact negatively on company efficiency, productivity and profits leading to major economic losses to the whole society. Silicosis is an added burden to the health service in South Africa. The disease is caused by exposure to respirable crystalline silica (RCS) dust. In the South African mining industry, there is an increased risk of tuberculosis among mineworkers exposed to RCS dust and those who develop silicosis. Silicosis is incurable but preventable and RCS dust control is the key. Extensive efforts have been deployed globally and nationally toward the elimination of silicosis. In South Africa, the mining industry set milestones for RCS dust reduction and silicosis elimination by 2013, now extended to 2024. The National Programme for the Elimination of Silicosis in South Africa has only been partially successful due to poor implementation of interventions, the complexity of interventions, and non-compliance with enacted policies. This may account for the fact that novice, current and former mineworkers are still being diagnosed with silicosis in the country. This study aimed to describe the existing implementation strategies and explore the facilitators and barriers to implementation of silicosis elimination interventions in the mining industry, South Africa.

Methods

A cross-sectional exploratory qualitative study was conducted using in-depth interviews among 18 participants selected purposively based on knowledge and experience in the mining industry. The Consolidated Framework for Implementation Research (CFIR) guided the development of the interview guides, data collection and analysis. Framework analysis was conducted and the transcribed data were coded using a hybrid of inductive and deductive coding to derive themes and sub-themes.

Results

18 participants consisting of representatives from DMRE, Minerals Council South Africa, MHSC, MOSH, mining companies, unions and an academic researcher were interviewed. The five main themes identified in this study were intervention-related factors, implementation-related factors, human-related factors, health-related factors and contextual factors. The strategies identified in the study were found to be part of the facilitators for implementation. The facilitators identified in the study were technological advancement, communication and dissemination of strategies, the Minerals Council's role, industry milestones, legislation, enforcement of regulations, monitoring and evaluation, and compensation benefits. The major barriers were the lack of implementation practices and inadequate enforcement.

Conclusion

In the study, CFIR framework was used to guide a systematic process that looked at the strengths and weaknesses of silicosis elimination in the larger mines under the leadership of the Minerals Council South Africa. A lot of work has been done in terms of communication, legislation, enforcement, provision of interventions and efforts from all stakeholders. There a is need to improve communication and feedback with mineworkers on the message of silica dust reduction, enforcement of legislation and policies.

Keywords: barriers; CFIR; dust controls; facilitators, interventions; milestones target; silica dust; respirable crystalline, mining, mineworkers

DEDICATION

This research is dedicated to my heavenly father – Almighty God thanking Him for his immense love, my supportive husband, and my beautiful children.

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LIST OF ACRONYMS

AMCU – Association of Mineworkers and Construction Union

CFIR – Consolidated Framework for Implementation Research

DALYs- Disability Adjusted Life Years

DMRE – Department of Mineral Resources and Energy

DOEL – Department of Energy and Labour

GDP – Gross Domestic Product

GOHN – The Global Occupational Health Network

GPES – Global Programme for the Elimination of Silicosis

HIV – Human Immunodeficiency Virus

ILO – International Labour Organization

LMICs – Low- and Medium-Income Countries

MHSC – Mine Health and Safety Council

MOSH – Mining Industry Occupational Safety and Health

NUM – National Union of Mineworkers

OEL – Occupational Exposure Limit

PTB – Pulmonary Tuberculosis

RCS – Respirable crystalline silica

TB – Tuberculosis

UASA – United Association of South Africa

WHO – World Health Organization

CHAPTER ONE: INTRODUCTION

This chapter presents a background to silicosis, - the different types and prevalence of silicosis globally and in South Africa, the public health importance of silicosis and elimination of silicosis. The problem statement highlights the burden of silicosis and respirable silica dust exposures in the gold mining industry. The purpose for the study, research question, aim and objectives are described. The chapter ends with a description of Consolidated Framework for Research in Implementation Research (CFIR) that was used in the study.

1.1 Background

Occupational diseases have an immeasurable effect on workers, their life, livelihoods, families and communities (Usseli and Yasin, 2021). In addition, the ill health of workers can affect a company's efficiency, productivity and profits, leading to major economic losses for the whole of society. Silicosis is an added burden to health services in the South African mining industry (Nelson, 2013).

Respirable crystalline silica (RCS) dust is generated when the earth's crust and rocks are drilled (Stanton et al., 2006). The RCS dust can be found in the ore body of gold, platinum, coal, manganese and diamond mines, in different concentrations. Silicosis, thus is an occupational lung disease that affects workers who are exposed to RSC dust in any of these commodities where the ore body contains RCS. The workers in industries or occupations such as tunneling, mining, construction, agriculture, glass and quarry are typically exposed to high levels of RCS dust, with workers in the gold mining industry being typically highly exposed. (Parks et al., 2004).

Silicosis is a pneumoconiosis - an occupational lung disease triggered by inhalation of dust, leading to inflammation and fibrosis of the lungs (Cullinan and Reid, 2013). Silicosis occurs when an individual takes in dust particles through the nose and/or mouth while working. The inhalation of RCS dust causes irreversible fibrotic nodules and scarring of the lungs which leads to severe dysfunction of the lungs (Greenberg et al., 2007). Mineworkers who are exposed to RCS may

develop silicosis and become ill, over time (CDC, 2002). The condition is progressive and symptoms may develop over many years or decades, even after exposure has ceased (Rees and Murray, 2007).

Silicosis manifests pathologically with lymph nodes in the chest and nodules in the lung, and clinically (only at very advanced stages of disease), with difficulty in breathing, cough, fatigue, fever and shortness of breath. The large majority of individuals with silicosis will be asymptomatic. Silicosis can present clinically as chronic, acute, or accelerated forms of the disease (Rees and Murray, 2016). Chronic silicosis occurs when an individual is exposed to low concentrations of RCS over many years. Accelerated silicosis happens when an individual is exposed to high levels of RCS for a shorter time (Rees and Murray, 2016). Acute silicosis manifests after heavy exposure to RCS in the work environment (Rees and Murray, 2016). An elaborated description of the types of silicosis is presented in table 1.

Table 1: Types of silicosis associated with respirable dust (Rees and Murray, 2016).

Pneumonoconiosis	**Description**
Chronic silicosis	The most common form of silicosis. Occurs > 15 to 20 years of exposure at low concentrations.
Accelerated silicosis (silicoproteinosis)	Occurs after short-term high exposure. Typically, 1-3 years of exposure is required. But may develop within weeks. Pathologically similar to alveolar proteinosis.
Acute silicosis	Silicosis manifests after less than 10 years of exposure. Associated with higher levels of exposure and more rapid disease progression.

Other diseases associated with RCS dust exposure are Caplan's syndrome (rheumatoid arthritis and lung nodules), emphysema, mineral airways dust disease, mycobacterial diseases such as tuberculosis, and lung cancer. Non-respiratory conditions related to RCS dust exposure are auto-immune diseases, chronic renal diseases and cardiovascular diseases (Rees and Murray, 2016).

In the South African context, silicosis in mineworkers is of occupational and public health importance. Exposure to RCS (with or without the presence of silicosis) is a risk factor for TB (Cowie, 1994; Ross and Murray, 2004; Ehrlich et al., 2021). In addition, mineworkers living with

HIV are at additional risk of developing TB because of a compromised immune system and exposure to silica dust (Corbett et al., 2000). Silicosis combined with HIV increases the risk of TB 15-fold in mineworkers compared to those who do not have silicosis and HIV (Corbett et al., 2000).

Silicosis affects mineworkers worldwide. Globally, the burden of silicosis is estimated at 12.9 thousand deaths and 665.7 thousand for DALYs (Chen et al., 2022). In South Africa, the incidence rate for silicosis in the gold mines was 23 cases per 10,000 employers (MHSI, 2021). The prevalence of silicosis in deceased gold mineworkers was 322/1000 persons (Mhlongo et al., 2022).

Elimination of silicosis can be achieved through high-level commitments at global, national, industry and employer levels. Silicosis is incurable and yet preventable. Prevention of silicosis can be achieved by reducing or eliminating exposures to RCS dust through the robust application of the hierarchy of controls for silica dust in the mining industry. Interventions to eliminate silicosis are primarily directed at dust control in mining operations and preventing exposure to RCS dust. Global and national intervention programmes have been initiated under the leadership of the International Labour Organization (ILO) (Fedotov, 1997) through the Global Programme for the Elimination of Silicosis (GPES) programme that is focused on eliminating silicosis by 2030. South Africa was part of the GPES programme that was launched for all countries affected by silicosis in 2004 under the leadership of the Department of Labour (Rees, 2006).

At the industry level, the South African Mining Industry (SAMI), adopted and implemented the NPES under the auspices of a tripartite alliance (representing the State, mine employers and employees). In South Africa, the Mine Health and Safety Council (MHSC) developed the milestones to further reduce RCS dust exposure below the regulated level of 0.1 mg/m^3. The milestones were first proposed and they were reviewed and updated in 2014 (Msiza, 2014). Further details are provided in the literature review (section 2.3.5). The original industry milestones for RCS exposure levels in the mines were not to exceed the occupational exposure level (OEL) of 0.1 mg/m^3. In 2014 the milestones were reviewed and the OEL was reduced to 0.05 mg/m^3 (Msiza, 2014).

1.2 Problem statement

Despite a silicosis elimination programme and implementation of interventions, SA is not reaching its target. The goal to reduce 95% of individual RCS dust exposure levels to below the OEL of 0.05 mg/m^3 in the mining industry has only been partially achieved. (Brouwer and Rees, 2020). The gold mining industry, in particular, still records RCS dust exposures and cases of silicosis (MHSI, 2020; Mhlongo et al., 2022). In addition to current mineworkers, former mineworkers still present with silicosis and silica-related diseases (Kgokong et al., 2018). This suggests there is a problem with the implementation of interventions to reduce RCS dust and eliminate silicosis in the mining. Few studies have looked at factors affecting the implementing of interventions to eliminate silicosis (Stanton et al., 2003; Hermanus, 2007; Murray et al., 2011; Rees, 2020).

The milestone that no new cases of silicosis be diagnosed in mineworkers who entered the industry from 2008 appears not to have been met as silicosis was diagnosed in young, female mineworkers who entered the industry after 2008 (Ndlovu et al., 2019). Additionally, in 2018 three new cases of silicosis were diagnosed. There is still a lack of information on new exposures in the mining industry and this is a major problem for silicosis elimination efforts. Thus, there is no recent data on silicosis cohorts as most of the cohort studies were on autopsy.

A cohort study, from 2006 to 2009 found silicosis present in working mineworkers (Knight et al., 2020). Also, according to the Minerals Council South Africa report, there has been an increase of 12% for exposures above recommended OEL in the mine companies between 2017 and 2018 (Minerals Council South Africa, 2019). The current OEL of 0.05 mg/m^3 for silica dust recommended by MHSC, may not be protective against silicosis (Brouwer and Rees, 2020) as silicosis is still prevalent in mineworkers (Mhlongo et al., 2022). Moreover, some countries in the European Union, the United States and Australia have lowered the OEL for RCS to between 0.025 and 0.05 mg/m^3 (Chanvirat et al., 2018). This is to ensure mineworkers are not exposed to silica dust. A cross-sectional study of employed black gold mineworkers showed that 20% of mineworkers who were exposed to dust levels at 0.1 mg/m^3 were reported to have silicosis after working in the mines for many years (Churchyard et al., 2004).

Mineworkers are still exposed to RCS dust and this is attributed to poor implementation practices in the mining industry. Thus, this has affected the elimination of silicosis in the South Africa mining industry.

1.3 Justification

Despite the implementation of the NPES and milestones set by the MHSC, the evidence suggests that South African mineworkers continue to be exposed to RCS dust and develop silicosis in the SA mining industry (Ndlovu et al., 2018a; Knight et al., 2020). This implies that the implementation of silicosis elimination programme has not been met fully. Hence, it is important to explore the facilitators and barriers affecting the implementation of interventions to silicosis elimination programme in SA. There has been no systematic study of the facilitators and barriers to the implementation of this programme. This study will provide information to inform recommendations for effective implementation.

1.4 Research Question

What are the factors influencing the implementation of interventions to eliminate silicosis in the South African gold mining industry**?**

1.5 Aim

To explore the factors influencing the implementation of interventions for the elimination of silicosis in the South African gold mining industry.

1.6 Objectives

1. To describe existing implementation strategies for interventions towards the elimination of silicosis in South African gold mining industry.

2. To explore facilitators of implementation for interventions to eliminate silicosis in South African gold mining industry.

3. To explore barriers to the implementation of interventions to eliminate silicosis in South African gold mining industry.

CHAPTER 2: LITERATURE REVIEW

This chapter introduces the prevalence of silicosis in current, former, and deceased mineworkers in South African mining industry. The key interventions for silicosis elimination in the mining industry and known factors affecting their implementation are presented. Studies exploring facilitators and barriers to interventions in different fields of study are also examined. The last section discusses the Conceptual Framework and research done using the framework.

2.1 Silicosis in South African mines

Silicosis is an ancient and historical disease in the gold mining industry, present even before the 1900s (Holman, 1947). The disease is progressive and occurs in mineworkers who are currently working, those who have left service and deceased mineworkers (Ndlovu et al., 2019; Ndlovu et al., 2018; Nelson et al., 2010). In South Africa, gold mineworkers continue to experience high morbidity and mortality due to silica dust exposures(Bloch et al., 2018). The burden of silicosis in SA gold mineworkers from the 1900s to date has shown a decrease (Nelson, 2013). Although, the mining industry still records the incidence and prevalence of silicosis (DMRE, 2020; MHSI, 2020).

2.2 Silicosis prevention and control strategies

Several strategies have been implemented to prevent and control silicosis in the mining industry. These include changes in legislation, policy and regulations, implementation of the GPES, creation of targets/milestones and adoption of international best practices to reduce RCS dust exposures and silicosis.

2.2.1 Hierarchy of controls

Silicosis and RCS dust are prevented and controlled by using various interventions. These interventions are defined activities set in place to help improve or eliminate disease occurrences (Fixsen et al., 2005). Primary prevention involves the suppression and elimination of RCS dust at

source using, for example, engineering methods to prevent the creation of dust, wetting methods to suppress dust generated, etc. This is the most important and most effective method to reduce mineworkers' exposure to RCS dust. Secondary prevention focuses on medical and administrative prevention methods, such as medical surveillance programmes to screen exposed workers to detect early disease and treatment for silicotuberculosis, and worker rotations and shift schedules that reduce time spent in dusty environments, respectively (Motshelanoka et al., 2005). Tertiary prevention comprises compensation and social benefits for current and former mineworkers with silicosis. It is the lowest level of prevention used to reduce the adverse effects of the disease (Knight et al., 2020).

2.2.2 Leon Commission of Inquiry

The National Union of Mineworkers' (NUM) determination to see efforts put into neglected mineworkers' health and safety in the mining industry, motivated the setting up of the Leon Commission of Inquiry in 1994 (Leon Commission, 1994). The findings by the Commission showed that there was a need to improve the standards for dust exposure and medical surveillance in the mines (Stanton, 2003). The Commission then recommended certain actions in the workplace which led to disease identification and targeted remedial solutions (Leon Commission, 1994). The Commission's findings led to the enactment of Mine Health and Safety Act (Leon Commission, 1994).

2.2.3 Mine Health and Safety Act

The Mine Health and Safety Act 29 of 1996 (MHSA), was enacted to protect mineworkers in South African mining industry (MHSA, 1996). This was a progressive piece of legislation that served to preserve and protect workers' health and safety in the mines. Employers were mandated to ensure that the health and safety of mineworkers are prioritized. According to the MHSA, Section 2 of Chapter 2, employers have the statutory duty to ensure the health and safety of mineworkers. Some of these responsibilities were delegated to the Occupational Hygienist (OH) and Occupational Medical Practitioner (OMP). The role of the OH is to monitor, and control exposures while that of the OMP is to monitor the impact of exposures and the detection and progression of silicosis and

other silica dust-related diseases, and make submissions for compensation (MHSA, 1996). The implementers of the Act, are expected to have critical top leadership support and invest in the elimination of silicosis. This should not be just a financial investment. The leadership must be visible and felt – body and heart to achieve implementation success in the mines (AngloAmerican, 2012).

The Department of Mineral Resources and Energy (DMRE), under the MHSA, requires that systems be in place for the measurement of workplace exposures, adherence to exposure limits, prevention and control of airborne pollutants, such as respirable silica dust. The mandatory Codes of Practice were developed in 2002, and in 2018 the guidelines were reviewed to include more measurements of airborne pollutants (DMRE, 2020). The Code of Practice contains the introduction of best practices, monitoring, audit systems, data verification, involving health working groups and sharing of findings of audits among mines with recommendations (DMRE, 2020). There has been a reduction in RCS exposure over the years due to the implementation of various control processes (DMRE, 2020). As a result of all of these interventions, there has been a downward and upward shift in RCS exposure to mineworkers for over 20 years.

2.2.4 National Programme for Elimination of Silicosis

In South Africa, the National Programme for the Elimination of Silicosis (NPES) implemented its activities through working groups at the provincial level. These assist in coordinating the implementation of interventions, evaluating programme success and communicating new developments (Motshelanoka, 2006).

South Africa's National Programme is aligned with The International Labour Organization/World Health Organization (ILO/WHO), Global Programme for Elimination of Silicosis (GPES), which was launched in 1997 (Fedotov, 1997). The global programme (GPES) supports countries in the establishment of national programmes to fit in the context of the country's goal toward the elimination of silicosis in the relevant industries (WHO, 2007). Twenty-two countries including China, Brazil, Chile, India, Thailand, Sweden, the U.S.A, and South Africa became part of the

collaboration (Fedetov, 2006). The national programmes then support the regional programmes on silicosis elimination plans and actions to be taken (Stanton et al., 2006).

2.4.5 Mining industry milestones

In the South African mining industry, the Mine Health and Safety Council (MHSC) is a tripartite structure representing the State, employers, and labour, which was established in 2003, in line with the Mine Health and Safety Act (MHSA). The State is represented by the DMRE, employers by the mining houses and labour by labour unions. The tripartite structure was established to enable equal representation of all stakeholders in the mining industry. The stakeholders meet to discuss and prioritize occupational diseases and injuries in the mining industry. The milestone targets for the elimination of silicosis were instituted by the MHSC. The target was to ensure mineworkers were not unduly exposed to RCS dust in the mines (MHSI, 2008). The milestones were reviewed in 2014 (Msiza, 2014). In recognition, that the OEL of 0.1 mg/m^3 for silica dust was not fully protective against silicosis, the milestone was reduced to 0.05 mg/m^3 (Msiza, 2014). Studies have shown that the OEL of 0.05 mg/m^3 is not sufficient to prevent silicosis completely but will provide health benefits for the mining industry (Brouwer and Rees, 2020). Table 2, shows the 2003 and reviewed 2014 milestones for RCS and silicosis in South Africa by MHSC.

Table 2: Mine Health and Safety Council's milestones and targets (MHSC, 2008; Msiza, 2014)

2003 Milestones	**2014 Reviewed Milestones**
95% of all exposure measurement results should be below the occupational exposure limit for respirable crystalline silica of 0.1 mg/m3 by December 2008.	95% of individual respirable crystalline silica measurements should be below OEL of 0.05 mg/m^3 by December 2024.
After December 2013, using current diagnostic techniques, no new cases of silicosis will occur amongst previously unexposed individuals before 2008.	Using present diagnostic techniques, no new cases of silicosis, pneumoconiosis, or coal worker's pneumoconiosis will occur amongst previously unexposed individuals.

2.4.6 Adoption of best practices

In 2018, Minerals Council South Africa (formerly known as the Chamber of Mines) took up the responsibility to represent some mining companies in SA (Baxter, 2019). The Council was established to seek and help its members with health and safety in the industry (MOSH, 2020). Health issues of interest included occupational lung diseases such as silicosis and TB. The Minerals Council South Africa had further shown committed efforts through the establishment of Mining Occupational Safety and Health (MOSH) in 2009 (MOSH, undated).

2.4.7 Compensation for silicosis

South Africa has a century-long history of compensation (Ehrlich, 2012). The high levels of silicosis and TB in the early years of mining led to the introduction of statutory compensation for mineworkers and the families of deceased mineworkers. The Occupational Diseases in Mines and Works Act, No. 78 of 1973 (ODMWA) is responsible for ensuring compensation for many occupational lung diseases including pneumoconiosis (e.g., silicosis, asbestosis and coal workers' pneumoconiosis), tuberculosis, chronic obstructive airways disease and asbestos-related lung cancer (Republic of South Africa, 1973). The funds for compensation are raised through levies that are paid by the mines based on RCS measurement (Ehrlich, 2012). The levy system, if implemented correctly, would serve as a deterrent to employers and promote the reduction of RCS levels in the mines. The level system was replaced with a calculated system for compensation in 1993 (Ehrlich and Rees, 2016).

The ODMWA also compensates living and former mineworkers who are found to have compensable occupational lung diseases of the cardiorespiratory organs. The Act is set by the National Department of Health (NDOH) and the adjudication of submitted compensation claims is done by the Medical Bureau for Occupational Diseases (MBOD) and compensation payments are managed by the Compensation Commission for Occupational Diseases (CCOD): occupational health cluster of the NDOH (Govender, 2019). The current Act is old, (promulgated in 1973) with limited reforms to keep up with current science and emerging new evidence. The compensation lump sum payments are not substantial, even at the maximum allowable amount (second-degree

certification) (Govender, 2019). This places a huge burden on families, communities and health services.

In recent years, successful class action lawsuits have resulted in settlements that have required mining companies to compensate mineworkers who developed silicosis and/or TB. The compensation is administered through Trusts. For example. the Q(h)ubeka Trust was established in 2016, for ex-mineworkers who suffered silicosis in the gold mining industry of Anglo-American South Africa Limited and AngloGold Ashanti Limited (Qhubeka Trust, 2022). The Trust covers 4,365 ex-mineworkers whose cases were presented by their legal representative for compensation claims (Qhubeka Trust, 2022). To qualify for compensation, the claimants must have worked for a qualifying mine for at least two years and have a qualifying silica-related disease.

Another example was the landmark settlement on behalf of gold mineworkers made in 2019 that led to the establishment of Tshiamiso Trust to administer the R5 billion available for compensation (Ryan, 2019; Tshiamiso Trust Annual Report. 2021). The six gold mining companies involved in this class action were African Rainbow Minerals, Anglo American SA, AngloGold Ashanti, Gold Fields, Harmony and Sibanye-Stillwater for ex-gold mineworkers who suffered from silicosis and/or TB (Spoor, 2018). To qualify for compensation the mineworkers must have worked in one or more qualifying mines between 12 March 1965 and 10 December 2019; confirmed to have had RCS silica dust exposure and contracted silicosis and/or TB. The settlement also covers the compensation of dependants of qualifying mineworkers (Tshiamiso Trust Annual Report, 2021).

2.3 Facilitators and barriers of silicosis elimination

Interventions to eliminate silicosis are primarily directed at dust control in mining operations, as silicosis is an irreversible condition. Some factors influence whether the interventions are implemented or not. These factors could be facilitators or barriers affecting implementation positively or negatively. Studies have reported the facilitators and barriers to the implementation of interventions to reduce RCS dust and eliminate silicosis in the mining industry. The facilitators include the tripartite structure, communication, training, and the current Covid-19 pandemic. The tripartite structure has created an avenue for representation and engagement of the government,

employers and unions. The tripartite structure has led to the introduction of guidelines, regulations, and codes of conduct for the health and safety of mineworkers (Hermanus et al., 2019).

Communication plays a vital role in ensuring information is received and disseminated accordingly. In communicating useful information in the mining industry for silicosis elimination, awareness and education come to play, creating an interaction for the exchange of ideas. Research by Chemiack and colleagues explored how awareness programmes were useful in communicating interventions and increasing implementation in workplaces (Chemiack et al., 2011). Also, a visible felt leadership in the industry is one that communicates effectively with its employees (Anglo-America, 2012).

Training as a programme has been a huge factor in equipping implementers in the mining industry to be able to execute their roles of applying interventions for silica dust control (GOHNET, 2007). Workshops and awareness programmes are been added sources of training programmes in providing the knowledge and expertise for the implementation of interventions toward silicosis elimination.

The current pandemic (Covid-19) has increased global attention on the health sector. Especially, bringing to the forefront the importance of health as an important enabler in the mines. The CEOs and boards of companies are now well informed about health matters in the mining industry due to the awareness and interventions instituted for the health and safety of mineworkers (Brouwer et al., 2020b).

The barriers are those factors that have hindered the effective implementation of the interventions for RCS dust reduction and silicosis elimination in the mining industry. Factors considered as barriers to implementation of interventions are poor enactment of legislation by certain mines, poor functionality of national elimination programmes, employers' lack of concern, the complexity of the implementation process and insufficient data on silicosis prevalence, and the effect of Covid-19 (Stanton, 2003; Hermanus et al., 2015; Anonymous, 2019).

Legislation and policies have been largely focused on ensuring the safety of workers and avoiding injuries in the workplace. Furthermore, policies on occupational diseases were not pronounced thus giving room for complacency in keeping records on dust measurements and disease prevalence (Stanton et al., 2006). The implementation of national programmes has been faced with drawbacks. The drawbacks are due to insufficient data on silicosis in the provinces thus leading to slow implementation of the intervention programmes (Motshelanoka, 2006). Poor data capturing and reporting of silicosis prevalence has contributed to the disease not being given the needed and immediate attention.

The lack of concern from certain employers and management teams towards implementing interventions in the mines is another contributing factor affecting the implementation of interventions in the mining industry (Lahiri et al., 2005). The management-focused and emphasized getting profits from the business and for the stakeholders that had invested in the mine (Stewart, 2020). Thus, the health of mineworkers are neglected and affected due to best practices are not followed during operations (Stuckler et al., 2013).

An evaluation study conducted, brought to light how certain MOSH-adopted strategies were complex. The adopted strategies are documented quiet well but access to technicians who could control the equipment or technologies becomes challenging (Hermanus et al., 2015). The buy-in of the management in the mining industry regarding the use of the control practices was not considered (Hermanus et al., 2015). Certain stakeholders such as the union raised issues of being neglected or not being involved in the whole adoption process for the interventions.

Moreover, silicosis cases reported by DMRE's MHSI and diagnosis cases by the Occupational Lung Diseases Working Group show varying figures due to several reporting systems (Brouwer and Rees, 2020). Research and data on silicosis globally and nationally are not sufficient and robust compared to other occupational health diseases such as TB and other diseases of public health importance (Anonymous, 2019). Additional, other barriers that have impeded the outcome of interventions are poor supervision, financial constraints to carry out standard control measures, the company operating procedures and risk assessment guidelines not mine specific, awareness training not addressing occupational health diseases, lack of consistency in management and poor

maintenance of old infrastructures in the mines (DMRE, 2020). Another barrier is the sudden emergence of Covid-19 in the world. The added health burden to the already loaded health system in our communities, nations and the world at large has affected the South African mining industry (Naidoo and Jeebhay, 2021). This is in addition to other occupational health diseases in existence and affecting mineworkers.

There have been several studies that have looked at factors affecting the implementation of interventions in an attempt to address health challenges and improve the lives of individuals. A survey conducted for workers and health workers in the agate mining industry revealed that in implementing interventions to reduce silica dust, lack of awareness and education gap were noted as barriers to preventing exposures in mine workers (Falk et al., 2019).

The systematic review by Means and colleagues identified 34 studies that used CFIR to guide qualitative research exploring the successes and failures associated with the application of interventions (Means et al., 2020). In a study conducted in Malawi, three health facilities were selected. In each facility, healthcare workers were interviewed on their experiences in implementing interventions for cervical cancer patients. The research was targeted at finding the facilitator and barriers affecting patients' screening and treatment for cervical cancer (Moucheraud et al., 2020). To improve the number of patients who came for screening and treatment of cervical cancer. A qualitative study was conducted by carrying out in-depth interviews. To help identify the facilitators and barriers nurses encounter when ensuring the care of persons with dementia (Hirt et al., 2021). One of the major facilitators highlighted was total commitment (Hirt et al., 2021).

2.4 Consolidated Framework in Implementation Research

The use of frameworks in research is to help in collecting information, translating research into practice and guiding implementation activities. One such framework is the Consolidated Framework in Implementation Research (CFIR). The CFIR framework helps to guide the systematic evaluation of various levels of implementation of interventions and to identify contextual factors that might influence the success of implementation programmes (Damschroder

et al., 2009). In research, the CFIR framework helps to explain what works, where it works, and why it works, across multiple contexts. The CFIR is useful for assessing the implementation of interventions to obtain evidence-based information for stakeholders and policymakers towards improving the implementation process. A summary of the CFIR is found in appendix iii.

The CFIR framework has thirty-nine constructs and five domains. (Damschroder et al., 2009; Qualitative Data, 2019). The five domains are the intervention, inner setting, outer setting, the individuals involved, and the implementation process. Each domain is classified into various constructs. The first domain, intervention characteristics speaks to the attributes of the interventions. How easy, complex, quality, strength, trialability, internal or external origin, ability to adapt to the intervention and cost of the intervention. The second domain represented as the outer setting deals with how resources, external factors, other industries, competitors, and policies affect implementation. The third domain which is the inner setting puts into consideration the size of the industry, networks, communication, leadership influence, acceptance and adaptation to change due to the intervention. The fourth domain, the characteristics of individuals focuses on the attitudes, beliefs, and capabilities of individuals administering the interventions or receiving the interventions. In the fifth domain, the process further investigates the whole planning, execution, champions and opinion leaders' influence, monitoring and evaluation.

Various studies have shown how CFIR framework had been used in identifying factors influencing the implementation of the interventions in different settings. In 2018, Naidoo and colleagues carried out an exploratory study using the CFIR framework to assess the enablers and non-enablers of implementing HIV intervention by community health workers in the Mopani district of South Africa (Naidoo et al., 2018). They were able to recognize what helped and what stood as barriers to HIV intervention in the district. Another study in Uganda clinics examined the barriers and facilitators of implementation for hypertension-HIV management using the CFIR framework and was able to identify the facilitators and recommended strategies to overcome the barriers to improve the health of patients and the health system (Muddu, et al., 2020). Similarly, a study explored the perceptions of health staff on the use of mobile health antiretroviral therapy applications for use in counselling patients. In the study, the facilitators and barriers to the use of mobile apps as an intervention were identified (McCreesh-Toselli et al., 2021).

2.5 Conceptual framework

The CFIR framework is a systematic guide that practically helps in evaluating the facilitators and barriers of interventions in an implementation process (Keith et al., 2017). The CFIR was used to describe the existing implementation strategies and explored the facilitators and barriers to interventions to eliminate silicosis in Gauteng, South Africa mining industry. The CFIR framework was adapted according to what was contextually relevant to the study. Five main domains and thirteen constructs were used in this study because of their suitability in the study setting. The five domains were Intervention characteristics, outer settings, inner settings, and individuals involved.

Figure 1, summarizes the CFIR domains and constructs that were adapted for use in this study to identify facilitators and barriers influencing the implementation of interventions to eliminate silicosis. The first domain which is the outer setting described the provision of resources to enhance implementation of interventions in the mines. In this domain, policies and training will be identified that have helped mineworkers to implement the interventions. The inner setting which has a link with the outer setting, speaks to the role of quality communication and dissemination of information on best practices in the mines. In the third domain, individuals involved: described mineworkers and all stakeholders in the mining industry. The stakeholders' knowledge about the interventions and implementation, ability to apply the best practices and factors that enable or deter successful implementation of interventions. The fourth domain, Intervention characteristics: considered the types of interventions in the mines and its characteristics. The final domain which is the implementation process, focused on how the best practices for the elimination of silica dust were carried out, monitored and evaluated in the mines.

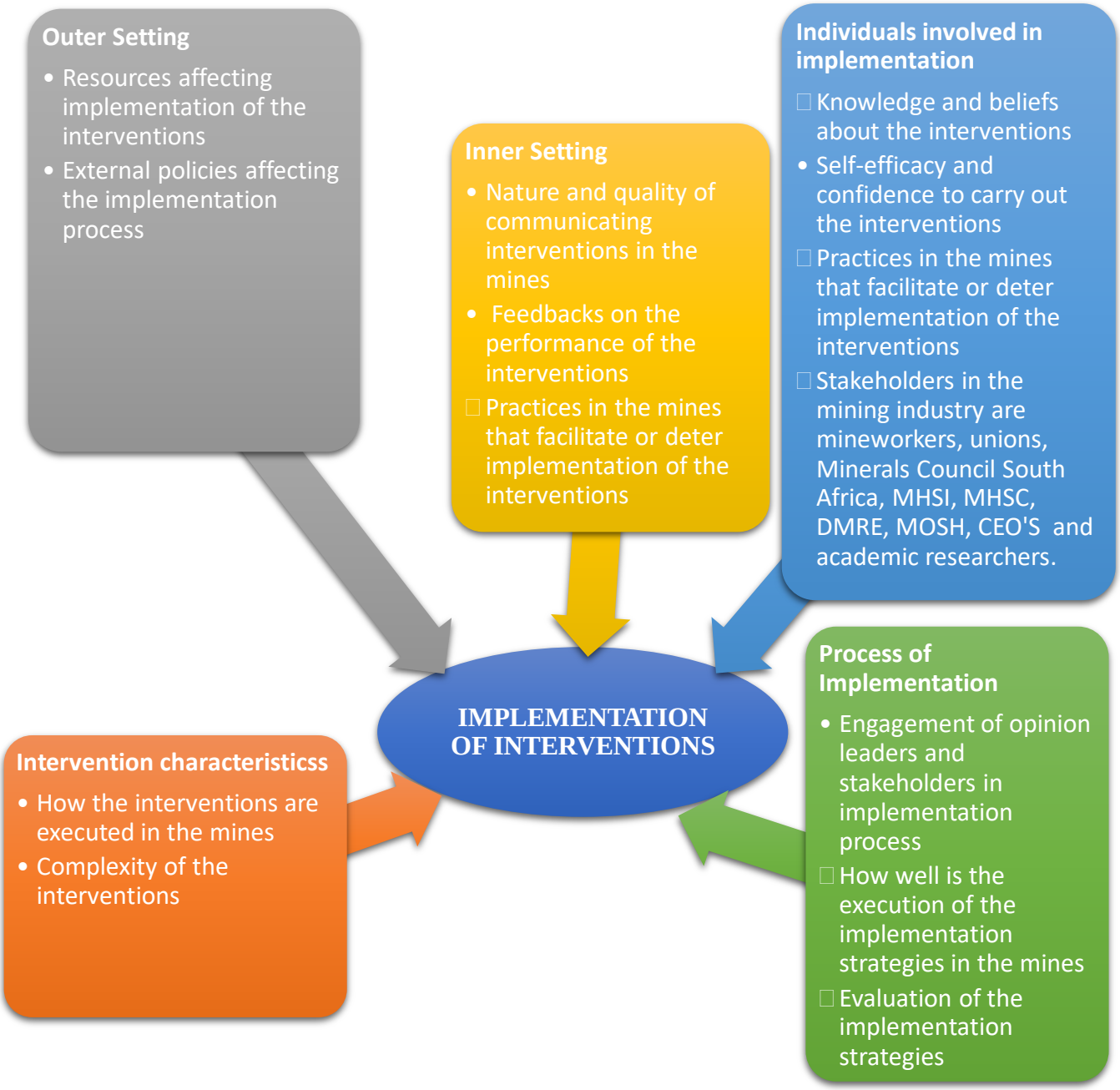

Figure 1: Conceptual framework adapted from CFIR (Damschroder et al., 2009).

CHAPTER 3: METHODS

This chapter describes the methods used to explore the strategies, facilitators and barriers influencing the implementation of interventions to eliminate silicosis in SA mining industry. The study setting, population, samples used, data management, and data analysis procedures in the study were extensively described. It concludes with the required ethics considered for the study.

3.1 Study design

This study used a cross-sectional exploratory qualitative design to investigate the facilitators and barriers that had affected implementation of interventions to eliminate silicosis in SA mining industry.

3.2 Study setting

The study focused on the gold mining industry in South Africa. For over a century, South Africa was the leading gold producer in the world but was ranked eighth in 2017 (MCSA, 2018). The gold mining industry contributed up to R24.3 billion to the economic growth of the country in 2019 (MCSA, 2020). The gold mining sector was selected due to its known association with activities that generate silica dust, high levels of silicosis and tuberculosis in mine workers (Ross and Murray, 2004). Although gold is found in the Free State and the North West Provinces, this study was conducted in Gauteng Province because most of the country's gold resources, mines and institutional headquarters are located in the Witwatersrand Basin which is found mainly in this province (Africa Mining Portal, undated).

3.3 Study population

The study population included implementers of the National Programme for the elimination of silicosis in the mining industry. These included Occupational Medical Practitioners (OMP), Occupational Hygienists (OH) and representatives of the employers, employees and government/industry.

3.4 Sampling

Participants were selected using purposive sampling based on their knowledge of the industry and years of experience with the implementation of interventions to eliminate silicosis in the mining industry. The 18 selected participants were those who could describe existing implementation strategies for interventions, explore the facilitators and barriers that had influenced the implementation of interventions to eliminate silicosis in the South African mining industry. The study participants are representative of the groups that formed the tripartite alliance (Sections 1.1, 2.2 and 2.45).

3.4.1 Eligibility criteria

To be eligible for inclusion in the study, individuals had to have a minimum of two years' work experience in their current position as of January 2021.

3.4.2 Participants

The tripartite structure was used as the basis for selecting and grouping participants selected. The tripartite alliance consists of the state (government), employers and union. The state was represented by the Department of Mineral Resources and Energy (DMRE). DMRE are the regulators who carry out audits and inspections in mines for compliance with guidelines and codes of conduct in the mining industry. The Minerals Council South Africa represents the employers (mine companies). Also, MHSC and MOSH are part of the tripartite structure. Mining Industry Occupational Safety and Health ensures the adoption of best practices that have been tested and proven by mines. The unions represent the mine workers and intercede for the workers on matters relating to their well-being. The union members were representatives from the Association of Mineworkers Construction Union (AMCU), National Union of Mineworkers (NUM), Solidarity and United Association of South Africa (UASA). The participants are described in Table 3.

3.5 Data collection

3.5.1 Interview guides

Four in-depth interview guides were developed for the study guided by the CFIR framework and objectives of the study (Appendices vi to ix). The first interview guide was for representatives of DMRE, Minerals Council South Africa and MHSC. The second interview guide was used for MOSH representatives. The third interview guide was for union representatives. The fourth interview guide was used for OH and OMPs. The interview guides contained open-ended questions about participants' roles and responsibilities in the elimination programmes, strategies for implementation, facilitators and barriers to implementation of interventions, monitoring, and evaluation of the process. Probes within each question were used to obtain more information.

3.5.2 Pilot of interview guides

The interview guides were piloted before the main study. One OH and an OMP who were familiar with silicosis elimination were interviewed. These interviews were not included in the main study. The interviews were transcribed and the responses were assessed to ascertain if the responses were suitable for the questions asked. The interview guide was then corrected for clarity where necessary. Ambiguous questions were revised for better understanding and probes were inserted to get further insight into questions.

3.5.3 Conducting the interviews

The interviews were conducted from September 2021 to February 2022. The interviews were conducted online due to Covid-19 restrictions and regulations. The selected participants were contacted via email, phone calls, text and WhatsApp messages. Some participants did not reply or accept the invitation to participate in the study while others accepted but did not participate in the study as they did not respond to messages despite several reminders. Thus, other participants who met the eligibility criteria were chosen as replacements. Six mine industries were approached but only three granted permissions for interviews. The other mines did not respond Interviews were scheduled for those who accepted to participate in the study and dates and times were communicated to the participants. Two days before the scheduled date, a

Microsoft Teams meeting invitation, information sheet (appendix iv), consent form for participation in the study (appendix v), and consent for audio recording (appendix v) were sent to participants through their emails. The participants responded and sent signed consent forms through email.

At the start of the interview, participants were reminded of the purpose of the study and requested to provide verbal consent for participation and recording. The interview only started when these were completed. During the interview, questions were repeated upon the request of the participants which was due to network issues or participants not understanding the question that was asked. After the interview, the names or identifying information of participants were removed from the transcripts and numerical codes were used for identification and documentation. The interviews were all conducted in English. The recording of the interviews was done in Microsoft Teams and with a backup recording device. During the interviews field notes were taken. Each interview lasted an average of 45 to 60 minutes.

3.6 Data management

The recorded interview transcript was downloaded from Microsoft Teams. To ensure the accuracy and completeness of the transcripts the researcher listened to each audio recording for the interview multiple times, cleaning the transcripts by editing all errors. Transcripts were identified with numerical codes to ensure confidentiality and saved on a password-protected laptop. The transcripts were imported into MAXQDA 2020 (VERBI) software for qualitative analysis.

3.7 Data analysis

Framework analysis was applied to the data as the research was guided by the CFIR (Srivastava and Thomson, 2009). Thus, there were *a priori* deductive codes based on the framework and study objectives. In addition, inductive codes were generated from the collected data.

The five steps guiding framework analysis: familiarization with the data of interest, identifying a thematic framework, coding the data, charting the coded data, mapping and interpreting the data were used (Ritchie et al., 2013). With regard to familiarisation, the researcher was fully engaged from the onset as she conducted the interviews and transcribed the recordings.

Subsequently, she listened to the audio recordings while reading through the transcripts and integrating the field notes to ensure all information was correctly captured. This ensured full absorption and understanding of the information generated. The transcripts were imported into MAXQDA 2020 software for further analysis (MAXQDA, 2020).

The data were coded using a hybrid of deductive and inductive coding. (Fereday and Muir-Cochrane, 2006). The researcher developed deductive codes on the facilitators and barriers from the CFIR framework and the study objectives. These were complemented by inductive codes that were derived directly from the data while reading through the transcripts. To achieve intercoder agreement, a colleague with experience in qualitative research coded five of the transcripts independently. Both coders discussed the codes derived and agreed on wording and definition which ensured consistency and validity in the analysis and resulted in the generation of the final codebook which the researcher used in coding the rest of the transcripts.

The charting of the coded data was achieved by summarizing the coded segments under each theme identified in a table. and the codes were matched with representative participant quotes which were summarized where needed, ensuring the meanings and information were not lost. Participants' concise words that did not need any summary were quoted as stated. The process of charting was reviewed to ensure themes and subthemes were not lost.

The final process in the analysis was the mapping and interpretation of themes generated. The researcher ensured concepts, associations, similarities and differences were well identified and interpreted in line with describing the strategies for implementation of interventions, facilitators and barriers influencing implementation of interventions to eliminate silicosis in SA mining industry.

3.8 Researcher's reflectivity

Here, I reflect on my perceptions and experiences before and during the research. I am a Master's in Epidemiology student specializing in the field of Implementation Science at the University of Witwatersrand.

Firstly, my role as an interviewer with the selected participants was official. I had no personal or work relationship with the respondents besides contacting them to invite them to participate and schedule the interviews when they were accepted. To the best of my knowledge participants responded to the questions with their opinions. Where necessary, questions were repeated or explained to the participants without unduly influencing the responses. The possibility of bias was minimized as I was only the interviewer which ensured consistency in whatever explanations or clarification was required. Secondly, my role as the researcher in this study was that of an outsider as I have never worked in the mining industry until this research encounter, thus enabling me to view the data objectively. I developed an interest in silicosis elimination in the South African mining industry when my supervisor introduced me to the topic. I was trained in qualitative research methods during the Master's coursework programme. My supervisors assisted and reviewed the analysis of the study data helping to eliminate any assumptions that could have affected my interpretation.

3.9 Ethical considerations

The study was approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (appendix x). Presentations about the research and its purpose were made to members of MCSA, DMRE, union and mine company's representatives to obtain permission to approach participants for the study. An approval letter was obtained from MCSA to enable the researcher to interview selected participants (appendix ii). Information obtained from the interviews was kept confidential and the transcripts were identified with codes.

CHAPTER 4: RESULTS

The results chapter presents findings from exploring the perceived facilitators and barriers that have influenced the implementation of interventions to eliminate silicosis in the SA mining industry. Presented are the participants' grouping, identified main themes and sub-themes from the study. In addition, the application of CFIR to the findings from the study was discussed.

4.1 Description of study participants

The participants interviewed are implementers of the silicosis elimination programme. They hold different positions and responsibilities in the SA mining industry. Details of the roles of the 18 participants who were interviewed are provided in table 3. The participants were occupational medicine practitioners (n=5), occupational hygienists (n=6), an environmental engineer, four union representatives involved in health and safety and one researcher who is also an OMP. The socio-demographic information of participants was not captured because it was not needed for the study.

Table 3: Description of participants

Group represented	**Participant grouping**	**Participant designation/role**
Government and industry	DMRE	OH 1 OMP 2
	Minerals Council South Africa	OH 3 OMP 4
	MHSC	OH 11
	MOSH	MOSH 12-Adoption Specialist
Employers	Mining companies	OH 6, 8, 16 OMP 7, 9, 17, Environmental Engineer 10
Employees	Unions	Union 5-Divisional Manager Union 14-Health and Safety Coordinator Union 15-Health and Safety Coordinator Union 18-Chairperson
Academics	Researcher	OMP/researcher 13

4.2 Study themes and subthemes

The six themes that emerged from the analysis of the interviews are strategies for dust control, intervention-related factors, implementation-related factors, human-related factors, health-related factors and context-related factors. The themes and sub-themes are presented according to CFIR domains and study objectives (Table 4).

Table 4: Themes and analytical framework

Main themes	Sub-theme	CFIR Domain	Definition	Facilitator/Barrier
Strategies for dust controls	Primary prevention	Intervention characteristics	Engineering control	Facilitator
	Secondary prevention	Outer setting	Industry milestones	Facilitator
			Legislation	Facilitator
			Codes of Practice	Facilitator
			Communication	Facilitator
			Awareness	Facilitator
		Implementation process	Monitoring and evaluation	Facilitator
	Tertiary prevention	Outer setting	Compensation	Facilitator
Intervention-related factors	Technological advancement	Intervention characteristics	Engineering controls – automation	Facilitator
			High cost of interventions	Barrier
			Intervention complexity	Barrier
	Practices and infrastructure		Outdated practices	Barrier
			Aging infrastructure	Barrier
			Poor maintenance	Barrier
	Knowledge and skills	Inner setting	Awareness and training	Facilitator
			Dialogue and collaboration	Facilitator
		Individuals involved	Poor literacy	Barrier
		Inner setting	Inadequate skills transfer	Barrier
Human related-related factors	Attitude of management or leadership	Inner setting	Employers' commitment to implementation	Facilitator
			Poor employer commitment to implementation	Barrier
			Focus on profits	Barrier
			Focus on production over health of mineworkers	Barrier
	Adherence to guidelines	Individuals involved	Mineworkers' unwillingness to adhere to guidelines	Barrier
	Attitude of mineworkers		Negative effect of compensation benefits	Barrier
	Supervision		Poor worker supervision	Barrier
Implementation-related factors	Communication	Implementation Process	Verbal (word of mouth)	Facilitator
			Written documents	Facilitator
			Virtual	Facilitator
			Language barrier	Barrier
		Individuals involved	Poor communication of implementation strategies	Barrier
	Minerals Council South Africa	Inner setting	Collaboration among mining companies	Facilitator
			Committees overseeing implementation	Facilitator
		Outer setting	Tripartism	Facilitator

	Mine Health and Safety Council		Mining summits	Facilitator
			New management in operation	Barrier
	Industry milestones		Lack of innovations to effect industry milestones	Barrier
	Legislation	Outer setting	Enforcement by DMRE	Facilitator & barrier
	Monitoring and evaluation	Inner setting	Lack of enforcement	Barrier
			DMRE reporting challenges	Barrier
		Outer setting	Regulatory inspection	Facilitator & barrier
		Inner setting	DMRE audits	Facilitator
			Poor DMRE reporting	Barrier
Health-related factors	Medical surveillance	Inner setting	Difficulty in tracking current and former mineworkers	Barrier
Context-related	Policy	Outer setting	Inability to move mineworkers from high-exposure jobs	Barrier
	Response during Covid-19	Inner setting	Increased health awareness	Facilitator
			Neglect of silica dust reduction practices	Barrier

4.3 Strategies for dust control

The existing strategies for implementing interventions to eliminate silicosis in the mining industry are classified into primary, secondary and tertiary prevention strategies.

4.3.1 Primary prevention

Primary prevention involves introducing engineering controls and best practices that help prevent mineworkers from RCS dust exposures in the mines. The strategies include continuous real-time monitoring, engineering controls and, more sophisticated, automated dust control systems. These controls help reduce the release of dust particles at source. Engineers are responsible for the operations of these systems. The interventions used vary among the mining companies. Some of the strategies are captured in the quotes provided by occupational hygienists from three different mines.

> *"The engineering control we have is automated dust suppression systems. This automated system is highly mechanized and thus reduces dust and our engineers are responsible for operating them"* [OH, Mine-09].

> *"Some of the controls we use in the mines are real-time monitoring, footwall treatment, winch cover, fogging systems, etc"* [OH, Mine-17].

"By using water, we installed fogging systems underground in all the places where we have dust so that small micron silica particle gets encapsulated into the water particles, and then you minimize the effect of silica dust, [OH, Mine-08].

4.3.2 Secondary prevention

Secondary prevention is used to support primary prevention strategies. They include industry milestones, legislation, codes of practice, communication, awareness, monitoring and evaluation.

Mine Health and Safety Council initiatives

The Mine Health and Safety Council (MHSC) organizes summits where the industry milestones and progress to attaining these are discussed. It was suggested that there is a need to focus more on the practicalities of implementation to meet the targets that have been set.

> *"In terms of the milestones, Mine Health and Safety Council conduct a summit on a three-yearly basis to monitor the progress of the agreements with milestone or the goals that have been set for the year. In the summits, so much is discussed but they should try and consider working more on how do we achieve the milestone targets we have set in place"* [OH, DMRE-1].

The milestone targets are set but there is little guidance on how to attain them. The methods in place to achieve the targets may not be keeping up with changes in the industry e.g. use of technologies. There is need to monitor and evaluate the methods to ensure silica dust reduction.

> *"The milestones are lacking in terms of innovation and systems. Its focus is on attainment. They are not moving with the times to be able to be on top of the issues that they need to be on top of. I think it's just for them to introspect and also try and review the methods that they use to attain.*

Legislation

The Mine Health and Safety Act legislates the need to appoint personnel as OHs and OMPs. According to the MHSA, every mine is mandated to have OHs measure and monitor RCS dust exposures. They also evaluate other possible risks that may occur during mining and implement control and elimination measures. The diagnosis of silicosis, and other occupational diseases, and monitoring of the health of mineworkers is the responsibility of OMPs.

Occupational medicine practitioners carry out medical surveillance and monitor mineworkers' health. In their mine, they have OH and OMP who ensure these duties are carried out accordingly.

> *"The health and safety reps have been helpful when it comes to workers' exposure to dust in the mine. In line with the Mine Safety Act, mines are required to have full-time health and safety representatives, who ensure the health and safety of mineworkers and protect workers from exposures of silica dust, which is what we have here in our industry"* [OH, Mine-16].

Codes of Practice (COP)

The mining industry has a Code of Practice that provides guidance on implementation of the best practices to reduce exposure to RCS dust. The health and safety representatives ensure that mineworkers adhere to the COP guidelines. The COP is available in the DMRE public domain or website. The procedures

> *"We've got a mandate, the mandated Code of Practice which requires us to have a dust management programme. In our mine, we have a dust management programme. First, you conduct the risk assessment, to look at people's exposures. Secondly, is the medical side of monitoring people's exposures through chest X-ray. The third is the use of engineering controls. And the fourth is what we do underground, we make sure that we apply best practices" [OH, Mine-16].*

Communication

Communication and dissemination of information in the mines were perceived to be important determinants for control strategies to be implemented. Information is shared from the MHSC to mineworkers using different communication mediums.

> *"At the Mine Health and Safety Council, we make sure that we communicate with our members first through the different mediums-verbally, documents and online recently. From the Mine Health and Safety Council side, we do have regional tripartite forums that meet every quarter for each region of all the mines in South Africa where communication is passed"* [OH, MHSC-5].

In the case of unions, information flows from the MHSC to the union branch leaders and then to the mineworkers.

> *"At the Mine Health and Safety Council, we make sure that we communicate with our members first through different mediums"*. [Union representative 5]

Mines have Mines and Safety forums which communicate information from the regional to the health and safety representatives to obtain information to share with workers.

> *"We communicate information within our structures, through Mine Health and Safety Council, and it is then cascaded down to the regional tripartite forum. The regions ensure communication with other forum representatives at the regional tripartite forum from all the mines in that specific region. They then take it* back to their *mines and then discuss it at Mines and Safety forums. The health and safety representativesget the necessary communication and take it down to representatives and workers"* [OH, MHSC-5].

A participant elaborated that the MHSC convenes with representatives of the state, employer, labour and other instituted committees to deliberate on issues in the mining industry. In such gatherings, codes of practices, regulations, matters about the mining industry, the health and safety of mineworkers are deliberated and agreed on.

> *"At the Mine Health and Safety Council, we make sure that we communicate with our members first through the different mediums-verbally, documents and online recently. From the Mine Health and Safety Council side, we do have regional tripartite forums that meet every quarter for each region of all the mines in South Africa where communication is passed"* [OH, MHSC-5].

MOSH assists mines to design communication to assist with the adoption of strategies to reduce RCS exposures.

> *"In its early stages, we make sure that we have a visit with the mine and its operation… we help the mine to design communication that can be widespread across the operation. Normally, we call this mine-wide- communication, where the mine will indicate its intentions to adopt an intervention"* [MOSH-12].

In addition, regulations and guidelines are communicated to the mineworkers using a pidgin language (fanakalo). The use of fanakalo makes it easier for information to be received well by the mineworkers.

> *"The workers are given instructions in fanakalo, which is a local language that they all understand having a mixture of Zulu, Afrikaans and English. They understand better with the language. They are told things they should do to avoid exposure to silica dust"* [OMP, Researcher-13].

Awareness

Awareness and training programmes were generally spoken of as strategies and facilitators for the implementation of interventions to eliminate silicosis. Materials and information on silicosis and silica dust are made available for the mineworkers so they can be informed and understand the severity of silicosis. Some mines have training centres where mineworkers receive annual or more regular training on various issues including the silicosis elimination milestones. The training material is produced by the Mines Qualification Authority but is delivered by the mines.

> *''We have a learning and development centre. Where certain things are taught to the mineworkers The basic training material would cover certain aspects, which are a legal requirement, industry milestones and the training is at least once a year"* [OH, Mine 6].

> *"The training programmes are developed through the Mines Qualification Authority but the training is provided by the mines themselves. This is conducted every year but I know of some mines where their training is monthly, while another mine does their training every three to four months, different mines have the way and time they conduct their won meeting''* [Union-5].

Monitoring and Evaluation

Monitoring and evaluation were seen as necessary factors in the implementation of interventions. The mines conduct periodic internal audits to assess compliance with the COP and the RCS OEL. The Mineral Council South Africa has an information system where mine companies under their leadership input exposures and cases of silicosis. This serves as a database to monitor and analyze exposures in the mining industry.

> *"Our part of monitoring and evaluation includes reporting and submitting the report. We do expect mines to report to us how many cases of silicosis or pneumoconiosis have been diagnosed for each year" [OMP, MCSA-4].*

Inspectors from the DMRE audit the mines and have the authority to impose fines and sanctions for non-compliance.

> *"Audit is conducted in the mines internally. Then DMRE visits the mines and audits the mines based on compliance. where they pick up non-compliance they will issue them with an instruction, based on Mine Health and Safety Act. It is there in section 54 or section 55 which require them to fix or require them to payfines for non-compliance, which is it's a very good system"* [Union representative-14].

The DMRE monitors RCS exposures, and the number of new and existing cases of silicosis on the mines and releases statutory reports for the industry.

> *"Through enforcement, inspectors go to the ground. They want to see if the guideline has been adopted, incorporated into the Code of Practice of that company and implemented. They look at the data as to whether interventions are effective or not because then it should mean reduction of exposures and cases"* [OMP, MCSA-4].

4.3.3 Tertiary prevention

Statutory compensation of mineworkers with the disease was noted as a tertiary prevention strategy and a facilitator for implementation of interventions to eliminate silicosis. The recent litigation and massive settlements to be paid by the industry to mineworkers with occupational silicosis and tuberculosis may provide further impetus for the industry to reduce RCS exposures.

"The biggest factor is compensation. I think they came up with some compensation for occupational lung diseases and that has helped" [OH, MHSC-11].

The use of PPE is a part of dust control that falls under tertiary prevention. This offers some form of protection from silica dust but it is the lowest form of prevention. Supervisors provide workers with PPE before they start their daily work activities.

"*The use of PPE, respirators, or dust masks; although that's perhaps not the most effective control, it's used with all the other engineering and administrative controls. The shift supervisors give the PPE to the mineworkers to help prevent them from inhaling dust*" [Union 5].

4.4 Silicosis elimination facilitators

Several themes emerged as facilitators of silicosis elimination. These were categorized as intervention-related, human-related, implementation-related and context-related.

4.4.1 Intervention-related factors

Technological advancements have played a role in silicosis elimination. Modern machines and systems have been installed in some mines. Watering-down of the work environment using high pressure to spray water removes RCS particles from the air and thus reduces dust exposure. These and more recent technologies, such as atomization, are highly automated and are operated and monitored by engineering teams.

"*Recently there has been a leading practice launch of instant atomization in our place. This generates a very fine* water mist *that captures particulates, allows for reduction of exposure to dust, our engineering people are in charge*" [OH, Mine-8].

4.4.2 Human-related factors

The attitude of mine management is an important factor when considering silicosis elimination. It was perceived that employers are committed to implementing the interventions for silicosis elimination as stated by the MHSC representative.

"*Our employers want to reduce the exposure; they make every effort to do what is required of them. They purchase the controls for dust prevention and try to do the right things*" [OH, Mine-08].

4.4.3 Implementation-related factors

Leadership

The leadership role of the Minerals Council South Africa is perceived to have facilitated the implementation of interventions for dust control. The Council has created several committees with experts leading the groups who advise and lead the adoption of best practices for silica dust elimination in the mining industry.

> *"I think some of the enabling factors are the Minerals Council structure, because, within the Council, you'vegot technical committees where subject matter experts sit in: the health professional committee, environmentgroup, environmental engineers committee, mechanical engineers, the committee from operations…. But one of the good things that have come from the Minerals Council, that we've been driving is industry best practices, and lead adoption practices"* [OH, Mine-8].

Through MOSH, the Minerals Council South Africa identifies good practices for RCS dust control and encourages the implementation of these practices across the mining industry.

> *"There is a drive from Minerals Council through MOSH learning hub. Where there's identification and adoption of leading practices. Companies performing in dust control and leading practices are identified. Once they're identified there is advocacy to ensure that there's widespread and adoption in the industry of such leading practices*" [OH, MCSA-3].

Collaboration

The MHSC tripartite meetings provide opportunities for collaboration and to get buy-in from stakeholders. The MHSC considered strengthening the implementation process by encouraging contributions from all representatives rather than imposing regulations in

the mining industry. Tripartism created room for consultations and collaborations among members to address issues affecting the mining industry.

> *"We at MHSC moved away from dictating to the industry but rather working together instead of policing. It is* working very *well for us. The dialogue with the industry, the collaboration and engagement that we are having is now yielding fruits"* [OH, MHSC-11].

Enforcement

Participants felt that the enforcement of regulations by the DMRE has helped to facilitate silicosis elimination. The DMRE, in its role as the regulator, enforces the codes of practice, guidelines and legislative frameworks. The department visits mines to conduct audits and inspections to evaluate compliance with the COP.

> *"We have different regulatory bodies. Our regulator DMRE then the Chamber of Mines gives us certain inputs that we do in terms of how we are faring toward the milestone requirement. They make sure we follow the Codes of Practice (COP) which is why they come to the various mines to conduct an audit and inspect what we do in the mines"*. [OH, Mine-6].

In addition to enforcement, through the DMRE, mines with RCS exposure levels above the OEL are required to pay a levy for non-compliance. If the levy system is fully implemented then there is a need to examine the reasons, we are still having overexposures in the mines. The levy system could also be reviewed to accommodate those companies that are complying with the standard OEL This is a misconception as the old levy system by DMRE is no longer implemented.

4.4.4 Context-related factors

During the Covid-19 pandemic, there was a greater focus and awareness about the disease which included silicosis. The stakeholders, the CEOs, managers and representatives in the mining industry became more aware of the health challenges faced by mineworkers.

> *"The pandemic has made government, Minerals Council, DMRE, unions, occupational practitioners and everyone focus on the diseases the mineworkers are facing in the*

mines. This is good because this has made even CEOs and boards of directors show concern about the health of mineworkers" [OMP, Mine-17].

4.5 Silicosis elimination barriers

In this section, the barriers are stated based on the emerging themes.

4.5.1 Intervention-related factors

Cost of interventions

Costs were perceived as a barrier to the implementation of interventions to reduce RCS levels as machinery and chemicals used in the control of RCS dust are expensive, especially those that are imported. Generally, large companies can afford to buy the correct machines and consumables but smaller mines cannot afford to purchase the best technologies.

> *"The chemicals they mix with water and spray on the walkways… lots of the mines don't want to use that chemical because it is costly. They use poor ways of controlling the silica dust. It then becomes poor, it creates shortcomings. The bigger companies have the money so they can purchase even the most recent engineering controls. But with the smaller mines, they do not have the means of purchasing the controls. Thus, they use what they have which might not be sufficient*" [OH, MHSC-11].

Complexity of the Code of Practice

The complexity of the COP was given as another factor that may affect the implementation of RCS interventions. According to a union representative, the COP contains words that are complex and technical and cannot be understood by mineworkers. It was felt that because the COP was written by educated individuals and not mineworkers, it cannot be easily understood by mineworkers. In addition, it was stated that union representatives do not explain the COP well enough to the mineworkers and this poses an implementation challenge.

> *"The area where there is a shortcoming is when the code of practice goes to the operational level. Some of the words are too technical for the union members at the operation to understand"* [Union representative-14].

Another union representative stated that sometimes mineworkers do not know what is required of them because of ambiguity of the wording in the COP. The participant further explained that

the COP is more of a theoretical document that needs to be written in a way that that mineworkers can understand.

> *"In most cases, we have instances of employees being ignorant. I mean the standard operating procedures; code of practices and risk assessments have been designed but these are all theories. The practicality of these practices is then a challenge"* [Union representative-15].

Outdated practices

A researcher noted that some mines are still using outdated interventions and practices for silica dust elimination. Some of these interventions are not as effective as they used to be as newer interventions have been developed over the years in other countries and are more effective.

> *"In terms of understanding the depth of what we are dealing with many of these controls are a bit old and outdated. If you go to some of these developed countries, they use better interventions that help reduce silica dust exposures"* [Researcher-13].

Poor maintenance

The DMRE representative expressed concern over the dilapidated and old infrastructure in some mines. Poor maintenance adversely affects the implementation of interventions. Most gold mines have been in existence for decades and, with time and usage, their infrastructure has deteriorated and some of the dust suppression interventions that were installed are no longer functioning properly.

> *"The other challenge that we are having in terms of implementing controls is the aging infrastructure. In the mines they are still using the old structures with no new developments thus ventilation becomes a challenge in underground mines*" [OH, DMRE-1].

Skills transfer

Failure to transfer generational knowledge or expertise in the mining industry is a barrier to implementation. This happens when older and experienced mineworkers retire and their knowledge is not documented or taught to others. There is no platform for such ex-mineworkers to transfer their skills or share their knowledge with the new generation of mineworkers. This creates a loss of skills and knowledge in the industry.

"We have a generational gap in between where you have all those old professionals in the mining industry that was in the system for a long time understanding everything, all of a sudden retiring. We did not close that gap by transferring lots of skills, to the few people that are coming in now. So, there is that departing of knowledge and training" [OH, MCSA-3].

4.5.2 Human-related factors

Employer commitment

Mine owners and managers are sometimes complacent and do not show interest in implementing interventions to eliminate RCS. They focus on production and making financial gains rather than on the safety and health of mineworkers. They feel and act as such because the impact of RCS dust and silicosis is not observed immediately.

"It's also behaviours, especially leadership behaviour, depending on how the leadership in that particular operation views the importance of eliminating occupational diseases. At times you find this challenge where people are more focused on production and giving more focus on safety, rather than focusing on occupational diseases. Due to its latency nature, that presents a level of complacency of the leadership not to act swiftly" [OMP, Mine-9].

Some managers in the mining industry are just concerned about drafting and documenting the necessary COP but in reality, there is no translation of the implementation practices into routine activities in the mines.

"The other challenge is that you get this code of practice which needs to be implemented at certain times. What management does is they will draft it and then they will just call the committee to sign. Let's sign this code of practice after signing it. They just put it in the cupboard. Implementation is a problem" [Union representative-15].

Unwillingness of mineworkers to follow guidelines

All the participants mentioned that human behaviour affected the implementation process for silicosis elimination in the mining industry. There have been cases of mineworkers' reluctance

to comply with guidelines and COP. Some mineworkers do not want to use the masks supplied to them because of discomfort while working.

> *"Some of the factors that have resulted in limiting silicosis elimination are people's behaviour, the only problem we have is workers do not follow standard procedure, and employees have the problem of not listening to instructions. You see workers do not want to do things the proper way and then they get to contact dust more than is required"* [OH, Mine-6].
>
> *''Sometimes the workers are given masks to put on. They will not use it but say that they are not comfortable with it or having difficulty in breathing'' [OH, Mine-16].*

Compensation benefits

Some mineworkers want to be compensated. Even when reminded of the consequences of RCS dust exposure on their health, they do not take prevention seriously because they see compensation benefits as a means to extra income.

> *"The other thing that has been seen as a barrier is someone gets to see that this person has been compensated for silicosis, they seem to be living a normal life to them. Some people deliberately put themselves in some form of harm's way because of compensation"* [OH, Mine-6].

Change in mine ownership

When mines are taken over by new owners, the new mine owners may come up with new management strategies which focus on production rather than continuing laid-down interventions and standard operating practices.

> *"Changing management is also a challenge because as the mines are sold the new owners focus more to maximize profit, saying that they have a short lifespan to maximize their profit based on the investment they have made. As a result, corners are cut, and things are not being taken care of as they should be"* [OH, DMRE-1].

Inadequate supervision

Poor supervision during mining operations may adversely affect the implementation of dust reduction strategies. During night shifts, senior managers who tend to work during normal office hours, are not available to monitor and supervise the mineworkers.

> *"Poor supervision mostly at night contributes to poor implementation. You will find out that one supervisor or OH is managing or overseeing more than five shafts. Also, because the top people have gone home, some supervisors do not do their job well during the night shifts. This becomes very challenging to handle over-exposures of mineworkers to silica dust"* [OMP, DMRE-2].

A participant felt that there are not enough occupational hygienists employed and therefore they are unable to stations or operation zones regularly.

> "*... the mines, they've got people that are employed as occupational hygienists who also go down and monitor the issues of compliance. However, with the number of people employed in the gold mines compared to the number of panels that they monitor, it is very difficult to reach all these panels in one year. In some of the panels, the occupational hygienist has not visited the panels for two years, but they are in charge of checking the risk assessment*" [Health and safety coordinator, Union representative-15].

4.5.3 Implementation-related factors

The implementation-related factors that stood out as barriers to the implementation of interventions to eliminate silicosis are the language barrier, inadequate enforcement, gaps in knowledge, failure to transfer skills, and monitoring and evaluation.

Language barrier

Communication with the mineworkers can be difficult. Some of the older mineworkers are not educated thus telling them what to do can be challenging. These workers can only understand their local languages and require an interpreter to explain how to implement interventions in the mines.

"It's common knowledge. It's difficult because you need to talk to people in a language that is understandable and people can communicate with each other. Therefore, we are using English as a medium to talk to people. What makes it difficult is that some of the people that work in the mines, like the older people do not understand English. Then you have to talk to them through an interpreter so that they can understand. It makes it a little bit difficult" [OH, Mine-16].

Poor communication of implementation strategies

"Big ideas" for implementing interventions but there can be a lack of translation of the intervention into practice. Sometimes the interventions are not carried out as stated but rather done as the individual feels or even changed to their understanding.

"One of the things that are always a bit of a challenge in any mine that I've worked in, a lot of times, we get exposed to this big idea on how we want to combat things. By the time it reaches the person on the ground, it's been very watered down or it will not be explained the way it was developed" [Researcher-13].

Inadequate enforcement

There is a need for the regulatory body, DMRE, to carry out more regular inspections. This would improve the enforcement of interventions for RCS dust reduction and promote silicosis elimination. Inadequate routine monitoring by the regulators has made some mining companies relax and not actively implement RCS dust reduction.

The other area is for the DMRE. They are also not doing enough occupational hygiene inspections and auditing. I also served in the Mine Health and Safety Council. I have not seen a report about occupational hygiene monitoring by DMRE" [Union representative-14].

Reporting of silicosis

The analysis and reporting of silicosis prevalence every two years by DMRE was noted as a challenge as it affects implementation plans and execution. In most cases of silicosis or high silica dust exposures remain unresolved due to delays in obtaining reports from the regulators.

Participants expressed the need to review and reduce the time delay in reporting silica dust and silicosis reports.

> *"There are a lot of reports that are generated by our members and submitted to DMRE quarterly. However, the results of the analysis only reach the industry two years later. Our reports from the DMRE, are lagging by two years. The collection of information analysis, industries only get them two years later* [OH, Mine-8].

The need for review and improvement in the time frame to publish DMRE annual reports should be considered as part of the implementation drive in assisting to reduce RCS dust in the mines as commented by a participant.

> *"I think the inspectorate division, there is opportunities for improvement in terms of reporting their data. Mostly we get lagging data of two years as to what were the results annually in terms of exposures. A more recent or more updated reporting will go a long way in indicating where we go in with our agenda"* [OMP, Mine-9].

A participant from the DMRE indicated that the delays are because data generated and submitted from the mining industry are analyzed manually which is labor-intensive and time-consuming.

> *"At DMRE, the system is currently being developed. The analysis is done manually, which is quite a labor-intensive exercise"* [OH, DMRE-1].

In addition, increases in the numbers of exposures, cases and prevalence of silicosis may be due to double reporting. This is due to mineworkers moving from one mining company to another in the pursuit of better opportunities.

> *"Another thing, the employees are nomadic in nature. They move from one mine to the next. So, if a person had been working at this particular mine say the beginning of 2021, they exit or they cease to be employed at that mine, they go to another mine. There could be double reporting of the same individual. But even that would be happening, the trends are showing quite an acceptable trend and an acceptable picture of how the industry is achieving the reduction of cases but not eliminating"* [OMP, DMRE-2].

4.5.4 Health-related factors

Due to changes in mining practices, mine workers are working for longer periods. Due to the long latency period of silicosis, cases of silicosis are being detected in mineworkers who have worked in the mines for many.

> *"The challenge we have now, is people who have worked so long in the industry, will have silicosis, it's a very high possibility"* [OH, Mine-6].

4.5.5 Context-related factors

The covid-19 pandemic and policy on occupation change in the mines were identified as context-specific barriers to implementation.

Response during the Covid-19 pandemic

The OH from MCSA stated that with the emergence of Covid-19, the country's economy and various mine companies' financial standing was affected negatively. The sudden, drastic financial loss and lockdown to contain the pandemic made some mining companies with their management concentrate on reviving their mine's financial capacity. The mine owners being intent on gaining lost production time, and profit recovery, thus compromised on following set procedures for silica dust elimination.

> *"With COVID, the economy has been hampered big time. As a result, the mines would want to maximize their profit and ensure that they do not misuse their budget. They would try to prioritize and obviously when you start prioritizing some things will suffer.*
> *"It's reporting, for instance, since COVID, everyone has been caught up in COVID. The reporting rates fell. Reporting by companies into the system has dropped. That's the issue"* [OH, MCSA-3].

Additionally, the policy on occupation change has not been given much-needed attention and emphasis. The policy was established to ensure that mineworkers were required to change their work area once they have been exposed to silica dust above the recommended OEL or diagnosed with any lung-related diseases. The policy according to the participant has not been enforced.

"There is also a minimum standard of fitness guideline that guides the industry in terms of their medical surveillance on the criteria of employees working in higher dusty risk areas. Based on their occupational health status, if a person shows signs of impairment in their lungs, they may not be placed in high-risk areas like the underground. The occupation
change is something that needs to be reviewed and implemented effectively, as not much is done for now" [Environmental Engineer-10].

4.6 Application of CFIR framework for implementation research

The CFIR framework was used as a guide to identifying the themes of the study. The themes all fitted into the CFIR domains, as shown in Table 4. However, not all the sub-themes matched into the CFIR. The CFIR framework can thus be used to analyze the facilitators and barriers affecting implementation of interventions to eliminate silicosis in other settings.

4.6.1 Intervention characteristics

In the Intervention characteristics, five constructs emerged as the perceived barriers: the complexity of interventions, the high cost of intervention, outdated practices, aging mining infrastructures, and inadequate skills transfer. This is in accordance with the constructs of CFIR and these factors are likely to impact negatively the implementation of interventions to eliminate silicosis in the mining industry.

4.6.2 Outer setting

In the outer setting, the constructs; industry milestones, legislation, and regulatory inspections were identified as perceived facilitators. These factors are similar to the CFIR construct that speaks to external policies that could influence implementation.

4.6.3 Inner setting

In the inner setting, the following constructs emerged as perceived facilitators: communication, awareness, and commitment of some employers to implementation programmes. The constructs under barriers were mine employers' focus on production and

poor commitment to the implementation of interventions. These identified factors relate to the CFIR constructs under the inner setting domain.

Individuals involved

All the constructs that emerged under this domain were perceived barriers: mineworker's unwillingness to adhere to guidelines in the mine, negative effect of compensation, and poor workers' supervision.

4.6.4 Implementation process

The construct that was relevant as a facilitator is the summits organized by MHSC and the barriers are inadequate enforcement and knowledge gaps. These factors are similar to the domain in the CFIR framework which looks at engaging stakeholders, execution and evaluation of interventions in terms of implementation.

CHAPTER 5: DISCUSSION

The study explored the strategies, facilitators and barriers that have influenced the implementation of interventions to eliminate silicosis in SA mining industry. The study was able to discuss the identified perceived enablers and gaps in implementation of interventions to the elimination programme for silicosis. This chapter further reflects on the findings from the study and compared them with previous research contributions. The relevance of the study was further discussed with regard to other studies. This section concluded with the strengths and limitations of the study.

The key findings in this study are the use of a systematic method to collect and document implementation factors surrounding silicosis elimination in the mining industry. The implementation factors are communication, legislation, enforcement, intervention and human-related factors,

5.1 Systematic method

In this study, the collection of data was systematically done using CFIR framework. The framework was found to be useful in outlining the positive and negative factors that have contributed to silicosis elimination. Thus, creating a better understanding of the various processes contributing to the system. For example, implementation factors were found to contribute largely as barriers to implementation. This is consistent with the findings from a systematic review, describing CFIR as a guiding tool in identifying evidence-based factors affecting the implementation of interventions in a health system (Means et al., 2020).

5.2 Communication

The study found communication to be an important strategy and a perceived facilitator for implementing interventions in the mining industry. The channel of communication is hierarchy in nature as information is received from MHSC and it gets down to the mineworkers. The means of communicating the implementation strategies are orally or in printed documents. Also, fanakalo a pidgin language was used in the past (since the start of mining) to build important communication bridges between mineworkers from various parts of the SADC

region, who had to work safely together in dangerous situations (Hurst, 2018). However, there was no mention of if feedbacks were obtained from mineworkers concerning silica dust control practices. The voices of mineworkers need to be heard as their opinions would make implementation productive. The study by Chemiack and colleagues, also emphasized the need for effective communication as it is a key to implementing interventions in an industry (Chemiack et al., 2011).

5.3 Legislation and enforcement

The appointment of occupational hygienists and occupational medical practitioners in the mines is a statutory requirement under the MHSA, sections 12 and 13 (MHSA, 1996). The engagement of the OH and OMP is a perceived facilitator because of the role they play in ensuring mineworkers' health and safety. It was noted in the study, that there are insufficient OH and OMPs in the mines. This poses a barrier to implementation because they are not able to monitor all the various shafts with the numerous mineworkers. This is agreeing with the study by Forna et al., 2023, who emphasized the need for sufficient OHs and OMPs in the mining industry as they contribute to disease detection and prevention in the mines.

According to findings from the study, tripartism recognizes within the various representatives where experts in the field of health and safety were drafted in to tackle matters on silica dust reduction. The representative's engagement has led to the introduction of guidelines, regulations, and codes of conduct for the elimination of silicosis. Also, Hermanus et al., 2019 discussed tripartism as an engagement centered on coming up with ways to ensure the health and safety of mineworkers are paramount (Hermanus et al, 2019). Along with this are the activities of MHSC in these summits to identify and resolve bottlenecks in eliminating silicosis in the mining industry (MHSC, 2022). There is an already well-organized system in place to ensure health and safety of mineworkers, making the framework a booster to implementation.

Enforcement as a perceived facilitator is evident in the DMRE system in place for regulating health and safety concerns. These include but are not limited to, amending existing legislation, codes of practice and guidelines, as described in DMRE annual report (DMRE, 2020). The findings from the research confirm that the DMRE, through the Mine Health and Safety Inspectorate, is a regulatory body that is committed to the enforcement of regulations for RCS dust reduction and silicosis elimination as contained in MHSA Regulations, Chapter 11,

Occupational Health, Sections 11.6 and 11.7 (MHSA, 1996). However, in the study inadequate enforcement was noted due to irregular monitoring by the regulators which gives room for the mines to become complacent to practices towards RCS dust control. In the United States of America, with its high-income economy, the lack of enforcement of regulations in the mining industry has been associated with an increase in coal workers' lung diseases (Perret et al., 2017). Yet another study further elaborated that with a lack of enforcement of regulations in the industry, over-exposures are bound to occur (Wu et al., 2016).

The MHSC milestone targets for silicosis, according to Brouwer and Rees's paper seem not to be realizable (Brouwer and Rees, 2020) due to implementation factors such as poor reporting. In addition, the reporting and publishing of mine companies' silica dust levels by the DMRE are not regular as the recent report does not indicate the OEL for RCS dust (DMRE, 2020). This may be a contributing factor to the enforcement of regulations. Records still show silica dust exposures above recommended OEL in the gold mines (Minerals Council South Africa, 2019) and new cases of silicosis have been reported even after the 2014 updated milestones (DMRE, 2020). Despite these challenges, the industry milestones of eliminating silicosis by 2024 may be realized if implementation of interventions is improved by the mine companies and is consistently enforced by the DMRE regulatory authorities

The two years of reporting RCS exposures and silicosis cases by the regulators were pointed out as one of the hindrances to adequate enforcement. Due to the extended period of waiting for the published industry results, cases might be forgotten or other factors could take over in the meantime. In addition, data generated and submitted from the mining industry are analyzed manually by DMRE which is labour-intensive, time-consuming and substantially prone to human error. Studies by Torres et al., in 1998, show that the DMRE has not been relenting in its efforts to improve its reporting system for occupational health diseases including silicosis. Thus, digitizing existing records and digitalizing future records by developing applications with purposefully designed software, would help reports to be analyzed timeously, effectively, efficiently and would be value-adding for the DMRE and the mining industry at large.

5.4 Monitoring and evaluation

The monitoring and evaluation carried out in the mines are based on the MHSA's influence and ensure that implementation can be achieved. The implementation process is monitored through

documented reports of cases and exposures submitted. Inspections and audits are then conducted by the regulators (DMRE) to check for the compliance of mine companies, reported RCS dust exposures and occupational lung diseases, and the health and safety of mineworkers. In this study, monitoring and evaluation are potential factors for the implementation of the interventions. However, participants expressed concern over irregular monitoring by DMRE and in the mine companies which has probably affected RCS dust reduction in the mines. This is consistent with the finding from a study on how programme monitoring and evaluation was stated as one of the keys to TB elimination in the occupational industries (Lonnroth et al., 2015).

5.5 Intervention-related factors

The challenges encountered with interventions were seen as a perceived barrier to implementation. These challenges include the high cost of interventions, difficulty in understanding the procedures for interventions and lack of sufficient expertise. In this study, it was noted that due to the cost of providing the engineering controls, some mines especially the small and informal mines do not have the controls installed in their mines. This is because the intervention is expensive and above the budget of the industry, implementation then becomes impossible. This draw back has prevented the mines from using the appropriate controls to reduce RCS dust exposures. Existing literature shows that when interventions are expensive implementation of controls to reduce or eliminate health issues becomes challenging (Pillarisetti et al., 2017).

Complexity of the Codes of Practice and guidelines emerged as perceived barriers to implementation. This is a challenge and makes it difficult for mineworkers to understand what needs to be done. Previous studies identified that mineworkers could not understand the outlined procedures documented with regard to silica dust reduction. As such implementation of interventions became challenging (Hermanus et al., 2015). This is in alignment with the findings in this study where silica dust interventions were complex and mineworkers did not have technical knowledge of the intervention.

The establishment of MOSH learning hub by the MCSA has the potential for creating an avenue for knowledge sharing in the mining industry. The MOSH adoption system has over the years made room for best control practices to be selected, tested and adopted in industry, to achieve the MHSC milestones. However, an evaluation study reported the pitfalls of the MOSH

initiative in the mining industry (Hermanus et al., 2015) and noted the non-involvement of mineworkers' opinions in the drafting of the guidelines for implementation of control practices (Hermanus et al., 2015). Another shortcoming of the MOSH best practice adoption system is that mineworkers found the guidelines to be too complex and difficult to understand (Hermanus et al., 2015). These findings are similar to the report obtained from this research in that mineworkers complained that they do not easily understand the guidelines for implementing the interventions.

To this end, the MOSH dust adoption team planned for this when they introduced the fogger system to eliminate RCS dust at source. The MOSH dust adoption team members, frequently visited mineworkers underground where the fogger unit was piloted as a pioneering RCS dust control best practice. By firstly gaining a shared understanding of the problem of RCS exposures, and then developing education tools (comic books, posters, workplace signage). They conducted face-to-face training and education sessions with the mineworkers during toolbox talks before a shift, armed with easy-to-understand pamphlets with graphics (pictures), to explain how dust suppression worked and why it is important for their health. This resulted in tangible action when the fogger unit was faulty on one occasion and mineworkers refused to work and be exposed to high levels of dust (Govender, 2023). Such education and training interventions can be hugely empowering for workers, and should never be underscored in pursuit of profits. Such interventions substantially contribute to the prevention of RCS exposures in the first instance whilst lowering adverse health impacts in the longer term.

5.6 Human-related factors

Findings from this study revealed that human factors such as employer commitment were a facilitator and also a barrier that could either expedite success or be a hindrance. In this study, it was noted that some mine leadership and managers champion interventions for silicosis elimination. In contrast, management in other mines was more concerned with the production of minerals, negatively influencing implementation. As an example, a study on the progress of patient care revealed that commitment from the organization’s leadership was a catalyst to the implementation of patient health and improvement (Hirt et al., 2021).

Consistently in a study, the poor attitude of some management towards implementing interventions for silicosis elimination was highlighted. They were centered on making more

profits for the mining company rather than focussing on workers' health (Lahiri et al., 2005). This is consistent with the findings in this study where certain employers are indifferent when implementing RCS dust interventions in the mines. They rather give priority to production over mineworkers' health. In 2013, Stuckler reported that management was more concerned with the profits they needed to generate, rather than the health and safety of mineworkers (Stuckler, 2013). This is in stark contrast to the ideals of the MOSH learning hub, where the MOSH Leading Practice Adoption Guide clearly states that the details of the leading practice must be accompanied by "detailed leadership behaviour and behavioural communication plans" (MOSH, 2020a). For health and safety performance targets to be achieved, individual behaviours towards one's health and safety as an inherent value is vital.

Knowledge gaps, failure to transfer skills between retiring and new workers (generational and institutional knowledge), literacy challenges, and watering down of ideas are issues pointed out by participants as contributory barriers to implementation. Where knowledge gaps exist and where workers are not educated on the inherent occupational risks, a robust communication and awareness strategy is critical. Language becomes a barrier when the mineworker is not able to understand how to implement interventions toward reducing silica dust exposures. In this study, the workers could only understand their local language except when an interpreter was involved. In another study on silica dust exposure for agate workers, the researchers highlighted low levels of education as a barrier to the dissemination of strategies for the control of silica dust in the industry (Falk et al., 2019). Similarly, the fogger unit example where workers were trained on-site, substantiates the notion that educated workers participate in control measures and implement interventions more effectively. Furthermore, knowledge and transfer of skills are sometimes lost due to a new generation of mineworkers coming into the industry where sustainable career pathways were not developed for posterity.

5.7 Lessons from Covid-19 response

The Covid-19 pandemic placed unavoidable constraints on the implementation of interventions for silicosis in the mining industry. This study revealed how attention and focus were shifted and the response was concentrated on fighting Covid-19 pandemic. The shift from silicosis and TB to Covid-19 has created a gap that will be visible in years to come. Two studies seem to affirm the findings from this study, where implementation of interventions and responses in the

mines were geared towards curbing the Covid-19 waves of infection, thus neglecting TB and silicosis interventions (Chopra et al., 2020; Khoza et al., 2020).

On the positive side, those mines that had good respiratory surveillance programmes and robust HIV/TB programmes in place would have been able to swiftly pivot (theoretically, at least) to more comprehensive Covid-19 controls such as daily symptom screening, physical distancing, respiratory etiquette (like good cough hygiene and regular handwashing), mask-wearing and even provision of Covid-19 vaccinations on site. It is thought that such tight controls could have prevented TB as well (Brouwer et al, 2020b). This is a contentious area and further studies are needed to document the impact of the pandemic, and respiratory controls on occupational lung diseases. Covid-19 brought to the forefront the importance of 'health', as an important enabler for 'safety' in the mines. The CEOs and boards of companies are now well-invested in health and the momentum for the prevention of other longstanding chronic diseases, like HIV, TB, and importantly silicosis, needs to continue (Brouwer et al., 2020b).

5.8 Strengths and Limitations

This is the first study that has used the CFIR framework to explore the facilitators and barriers influencing implementation of interventions to eliminate silicosis in the South African mining industry. The effective use of this framework helped in the development of the interview guide and effective primary data collection. Participants were grouped based on the tripartite structure which provided a comprehensive representation of the stakeholders in the mining industry. This diversity of the stakeholders in the mining industry and their committed efforts adds to the richness of the study.

The limitation of this study is that only large companies were included in the study and the smaller mines that are not members of Minerals Council South Africa were excluded.

CHAPTER 6: CONCLUSION

This chapter provides suggested recommendations for achieving the reduction of RCS dust and elimination of silicosis in the SA mining industry. The areas of need for further research, contribution of the study to research and the conclusion.

6.1 Recommendations

The recommendations have been described and suggested following the roles of various stakeholders, implementers, all of who have a role to play in the reduction of RCS dust and silicosis elimination in the mining industry. The success of eliminating health issues in the mining industry lies in the successful acceptance, adaptability, sustenance and evaluation of interventions implemented. To ensure elimination of silicosis and achievement of the 2024 milestone target the implementation process is then a necessary factor to consider.

In sustaining the implementation of interventions, monitoring and evaluation can never be overlooked but rather enhanced greatly. The regulators, the DMRE needs to improve occupational hygiene inspections in the mine companies. The enforcement of guidelines has to be strengthened both in the mines and with the regulators. In terms of reporting exposures and cases by DMRE, the department should follow up on cases and immediately trigger actions commensurate to the cases.

In the mines, the number and services of occupational hygienists and occupational medical practitioners can be improved upon as their expertise contributes to the implementation process. Furthermore, leadership and supervisory roles in the mining industry should be made accountable for the responsibilities they hold. The accountability of the leadership roles will be a boost to human behaviour and management in the mining industry. Ex-mineworkers exposed to RCS dust can be incorporated into programmes that will do a follow-up of their health and adaption to life.

The spirit of care and lessons learned from the COVID-19 pandemic could be incorporated to strengthen respirable silica dust, silicosis and TB management in the mines. The swift response, constant attention, monitoring and collaboration of every stakeholder in the mining industry is

the driving force needed in ensuring elimination of silicosis in the South African mining industry.

For further research the opinions of implementers and mineworkers who are underground in the mines can be interviewed to obtain their opinion towards silicosis elimination. The mining companies, including small-scale mines, not under the membership of the Minerals Council South Africa should be considered. Human behaviour (both from the leadership and mineworkers) and how that have affected the implementation of interventions in the mining industry, needs to be further studied. The measures put in place during Covid-19 (exposure monitoring and medical surveillance) can be studied and incorporated into the existing interventions toward the elimination of occupational lung diseases. In addition, a well-designed epidemiological study of mineworkers' perceptions towards silicosis elimination could also be considered.

6.2 Conclusion

In this study, CFIR framework was used to guide a systematic process that looked at the strengths and barriers of silicosis elimination in the larger mines under the leadership of Minerals Council South Africa. The study does show that a lot is being done in terms of keeping up with best practices to reduce silica in terms of communication, legislation, enforcement, intervention and human-related factors and getting the message down to the mineworkers. However, the study also showed that there is room to improve the activities towards silicosis elimination. This would be in terms of improving communication, ensuring that mineworkers are getting the correct messages and that there is feedback from mineworkers so that their voices are being heard. We need to be sure that mineworkers understand the messages, changing their behaviour and practices to reduce RCS dust because we are still seeing cases of silicosis in the mining industry.

There is a legislation in place but it needs to be enforced and maybe seek for better ways to be implemented. The interventions have been made available but it is important to ensure that they are being implemented at the grassroots for mineworkers' health and safety. The policies have been drafted but strengthening the weaknesses found in the policies is necessary. The mining industry must continue doing the right and good things that they are doing. This study in conjunction with past and future studies can form evidence for occupational health and

implementation science departments on areas for potential improvement to eliminate silicosis in SA by 2024.

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APPENDIX I: PLAGIARISM DECLARATION FORM

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I CHINYELU JOSEPHINE PATRICK_____(Student number: 1929376) am a student registered for the degree of MSc Epidemiology (Implementation Science) in the academic year 2020_____.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/orwithout acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided workexcept where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection)software indicating the level of plagiarism in my research document.

Signature:  Date: 01/06/2023

APPENDIX II: APPROVAL LETTER FROM MINERALS COUNCIL SOUTH AFRICA

24 August 2021

The Ethics Committee
University of
Witwatersrand
Johannesburg

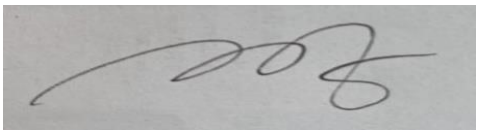
Dear Sir/Madam

Support for study: Facilitators and barriers influencing implementation ofinterventions to eliminate silicosis in the South African mining industry

The Minerals Council South Africa welcomes the above-mentioned study and hereby providesits letter of support for it.

The study will be conducted by Ms Chinyelu Josephine Patrick (Student number: 1929376), who is studying for an MSc Epidemiology in the Division of Epidemiology and Biostatistics, School of Public Health, University of the Witwatersrand. Her supervisors are Dr. NtombizodwaNdlovu, Dr. Oludoyinmola O. Ojifinni and Dr. Vanessa Govender.

We look forward to the outcomes of the
study.Yours sincerely



Dr Thuthula BalfourHead: Health

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APPENDIX III: THE ORIGINAL CFIR FRAMEWORK (DAMSCHRODER, 2009)

Intervention characteristics	Outer setting	Inner setting	Characteristics of Individuals	Process of implementation

- Intervention source
- *Evidence Strength & Quality*
- **Relative advantage**
- **Adaptability**
- *Trialability*
- **Complexity**
- *Design Quality & Packaging*
- **Cost**
	- Patient Needs & Resources
	- *Cosmopolitanism*
	- Peer pressure
	- *External Policy & incentives*
		- **Structural Characteristics**
		- Networks & Communications
		- Culture
		- Implementation Climate
		  - **Tension for Change**
		  - **Compatibility**
		  - Relative Priority
		  - **Organizational Incentives & Rewards**
		  - *Goals & Feedback*
		  - Learning Climate
		- Readiness for Implementation
		  - **Leadership Engagement**
		  - **Available Resources**
		  - Access to Knowledge & Information
			- *Knowledge & Beliefs about the Intervention*
			- *Self-Efficacy*
			- **Individual Stage of Change**
			- Individual Identification with Organization
			- Other Personal Attributes
				- *Planning*
				- **Engaging**
				  - Opinion Leaders
				  - Formally Appointed Internal Implementation Leaders
				  - **Champions**
				  - External Change Agents
				- Executing
				- *Reflecting & Evaluating*

APPENDIX IV: STUDY INFORMATION

Study title: Facilitators and Barriers influencing implementation of interventions to eliminate silicosis in the South African mining industry

Good day Ma/Sir

Introduction:

I, Chinyelu Patrick am researching "Facilitators and Barriers influencing implementation of interventions to eliminate silicosis in the mining industry Gauteng, South Africa". Research is a process used in seeking new knowledge. In this study, we want to learn the implementation process involved in carrying out the interventions; facilitators, and barriers to implementing the interventions. This would help in giving useful recommendations on how to improve the implementation of the interventions to achieve success towards eliminating silicosis in the mining industry. This research may be published in a journal and may be used to inform policymakers in the South Africa mining industry.

Invitation to Participate: I am inviting you to take part in the research study.

What is involved in the study: The study is an explorative qualitative study. If you agree to participate in this study, a face-to-face or online interview will be conducted for 45mins. The questions to be asked are based on your perceptions, knowledge, and experiences in the mining industry. The interview will be recorded for accuracy and accountability. For the recording of the interview, your consent will be needed.

Risks of being involved in the study: There are no foreseeable or expected risks in the study. There may be unknown risks.

Benefits of being in the study: The benefits of participating in the study are to contribute knowledge to research and inform policymakers in the government and mining industry. Information about the study and the results will be available.

Participation is voluntary

Payments: There will be no payment for participation in this study

Confidentiality: Normally personal information will be treated in the strictest confidence and will only be available to the Principal Investigator (PI) and his/her supervisor, in the case wherein the PI is a postgraduate student. The only exceptions - and all of them are rare - would normally be:

1. personal information may be disclosed if required by law
2. the Human Research Ethics Committees of the University may exceptionally require personal data to respond to a formal complaint, or for a compliance audit
3. the South African Health Products Regulatory Authority (SAHPRA), which is the successor body to the South African Medicines Control Council (SAMCC), might conceivably require access to personal data if conducting an investigation into a drug trial.

If results are published, this may, exceptionally, lead to cohort, or more rarely, individual identification. All data collected in the course of the study will be securely retained for two (2) years if a scientific publication arises from the study and six (6) years if there is no publication. Thereafter it will be destroyed accordingly.

Outputs: The study is intended to inform us about the facilitators and barriers to implementing interventions for silicosis elimination in the mining industry. The results of the study will be shared with you once the study is completed.

Contact details of researcher/s: In case of further information please e-mail and telephone contact details of the Principal Investigator and her supervisor are provided below:
Chinyelu Patrick, Principal Investigator, telephone no. 0780557373, or by e-mail at 1929376@students.wits.ac.za,
Dr. Ntombizodwa Ndlovu, Supervisor, on telephone no. 0117172311, or by e-mail at zodwa.ndlovu@wits.ac.za.
Contact details of HREC administrator and chair – for reporting of complaints/problems.

This study has been approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg ("Committee"). A principal function of this Committee is to safeguard the rights and dignity of all human subjects who agree to participate in a research project and the integrity of the research.

If you have any concerns over the way the study is being conducted, please contact the Chairperson of this Committee who is Professor Clement Penny, who may be contacted on telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011 717 2700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

Thank you for reading this Study Information Sheet.

Date: Month and Year only

APPENDIX V: INFORMED CONSENT FOR THE STUDY

PARTICIPANT CONSENT SHEET

Project Title: Facilitators and Barriers influencing the implementation of interventions to eliminate silicosis in the South African mining industry

1. I have been given a Participant Information Sheet which explains the nature and processes involved in this study, which is attached hereto;
2. I was given time to read it, or had it read to me, in the language I best understand;
3. I was given time to ask any questions I wanted to and found any answers given to me to be reasonable and satisfactory;
4. I believe I fully understand why the study is being conducted and what the intended outcomes will be;
5. I understand that there will be no immediate benefit to me, should I agree to participate, nor will I receive any payment; conversely, participation will not cost me anything but my time;
6. I understand that, even if I initially consent to take part in the study, I may subsequently withdraw at any time and would not be required to give any reasons; if that happened, any data collected about me for the purposes of the study would immediately be destroyed, unless I give consent for it to be retained
7. I have been given a range of contact details, listed below. If I require further information or become concerned about any aspect of this study. I am free to speak to any of these contacts.

Contact details of researcher/s: In case of further information please e-mail and telephone contact details of the Principal Investigator and her supervisor are provided below: Chinyelu Patrick, Principal Investigator, telephone no. 0780557373, or by e-mail at 1929376@students.wits.ac.za, Dr. Ntombizodwa Ndlovu, Supervisor, on telephone no. 0117172311, or by e-mail at zodwa.ndlovu@wits.ac.za.

Contact details of HREC administrator and chair – for reporting of complaints/problems. This study has been approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg ("Committee"). A principal function of this Committee is to safeguard the rights and dignity of all human subjects who agree to participate ina research project and the integrity of the research. If you have any concerns over the way the study is being conducted, please contact the Chairperson of this Committee who is Professor Clement Penny, who may be contacted on telephone number 0117172301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011172700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

Name of Participant: _____

Date: _____

Place: _____

Signature or mark _____

Witnessed by:

Name of Witness: _____

Signature: _____

Date: _____

CONSENT FORM FOR AUDIO RECORDING OF STUDY PARTICIPATION

Project Title: Facilitators and Barriers influencing implementation of interventions to eliminate silicosis in the South African mining industry

I hereby consent to the audio recording of the interview.

I understand that:

- The recording will be stored in a secure location (a locked cupboard or password-protected computer) with restricted access to the researcher and the research supervisor.
- The recording will be transcribed and any information that could identify me will be removed,
- The recordings will be erased within either (a) two (2) years of the publication of the research findings, or (b) six (6) years if no publications arise from this research
- Anyone wishing to access this information in the future will first have to obtain the approval of the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg
- Direct quotes from my interview, without any information that could identify me, may be cited in the research report or other write-ups of research.

Name of Participant: _____

Date: _____

Place: _____

Signature or mark _____

Witnessed by:

Name of Witness: _____

Signature: _____

Date: _____

APPENDIX VI: INTERVIEW GUIDE FOR DMRE, MINERALS COUNCIL SOUTH AFRICA, MINE HEALTH AND SAFETY COUNCIL REPRESENTATIVES

Topic: Facilitators and Barriers influencing implementation of interventions to eliminate silicosis in the South African mining industry.

Background information

1. Please describe your role, position, and responsibilities with respect to occupational health in the mining industry?

   Probes:

   a. What is your area of expertise?

   b. How long have you had this role?

   c. What is your role in the silicosis elimination programme in the mining industry?

Intervention characteristics

2. Describe the silicosis elimination intervention(s) you oversee or are involved in?

   Probe: a. How is the intervention being implemented?

3. In your opinion, tell me how well the intervention is working?

   Probes:

   a. What aspects of the intervention are working well?

   b. What aspects of the intervention are not working well?

   c. What is being done to address the challenges identified?

Inner setting

4. What policies have been put in place towards ensuring the implementation of the interventions?

   Probes:

   a. Describe how the policies are disseminated to the mining industry and relevant bodies?

b. How does the government get feedback to ensure the policies have been communicated properly or understood?

Outer setting

5. In your opinion, what factors encourage the implementation of the interventions?
   Probes:
   a. Describe the awareness programmes organized by the government to assist in the implementation of the interventions?
   b. What legal framework or regulations have the government established to ensure the implementation of the interventions by the mining industry?
   c. What corrective measures or action is been taken against non-compliance to the implementation of interventions?
   d. What commitments or actions have been done toward silica elimination?
   e. How do you evaluate the mining industry to ensure the implementation of interventions is done according to standards?
   f. In what ways have resources been provided from the government to assist the implementation of the interventions in the mining industry?
6. In your opinion, what do you think limits the implementation of the interventions?
   Probes:
   a. To what extent have the government policies influenced the implementation programme?
   b. What system is in place to ensure the mining industry comply with government policies on silicosis elimination?
   c. How are the policies and regulations on silica dust exposure limits enforced by the government?
7. What suggestions do you have to improve the implementation of the interventions?

Individuals involved

8. Who is involved in conducting the implementation process?
9. To what extent do you feel confident that the mining industry can implement the interventions?
10. To what extent do you feel the mineworkers have adequate knowledge about the implementation process?

Implementation process

11. What plans are in place for conducting the monitoring and evaluation of the implementation process in the mining industry?

    Probes:

    a. How often is the evaluation conducted? monthly, quarterly or yearly?
    b. What is the opinion of the government towards the implementation of the interventions?

12. How do you receive reports or information about the evaluations for implementing the interventions?

    Probe: a. How is the information from the reports used for the benefit of eliminating silicosis?

13. What challenges do you face concerning reporting of the process?

    Probe: a. How can the reporting of the implementation process be improved?

APPENDIX VII: INTERVIEW GUIDE FOR MINING INDUSTRY OCCUPATIONAL SAFETY AND HEALTH (MOSH) REPRESENTATIVES

Topic: Facilitators and Barriers influencing implementation of interventions to eliminate silicosis in the South African mining industry.

Background information

1. Please describe your role, position, and responsibilities with respect to occupational health in the mining industry?

   Probes:

   a. What is your area of expertise?

   b. How long have you had this role?

   c. What is your role with regard to the silicosis elimination programme in the mining industry?

Intervention characteristics

2. Describe the silicosis elimination intervention(s) you oversee or are involved in?

   Probe: a. How is the intervention being implemented?

3. How was the implementation of the intervention developed?

   Probes:

   a. What aspects of the intervention are working well?

   b. What aspects of the intervention are not working well?

   c. What is being done to address these challenges?

Inner setting

4. How are the implementation strategies communicated in the mines?

   Probes:

   a. How do you get feedback?

b. When you do not receive feedback what is the next step of action?

5. In your opinion what factors encourage the development and implementation of the interventions?

   Probes:

   a. How does the "tripartite structure" contribute to the development of the interventions?

   b. How have the milestones targets been achieved through the implementation of the interventions for silicosis elimination?
   c. What is the role of education, training, and awareness programme towards the implementation of the interventions?

6. In your opinion what do you think limits the implementation of the interventions?

   Probes:

   a. How has the complexity of the interventions affected implementation?
   b. How has the implementation of interventions affected the daily work routine of mineworkers?
   c. How have the following factors affected the implementation of the interventions negatively? (Availability of resources needed, Cost of the interventions, Management's commitment, Mineworker's opinion, government policies and regulations).

7. What suggestions do you have to improve the implementation of the interventions?

Outer setting

8. How are resources made available to ensure implementation of the interventions?

Probe: a. How do you make available the information or materials regarding the implementation process to mineworkers?

9. How are the mine workers empowered to enable them to perform their job regarding the implementation of the interventions?

   Probes:

   a. How well do you think the training prepared them well for the implementation process?

b. How is the training programme for the implementation of the interventions how is it sustained?

Individuals involved

10. Who is involved in conducting the implementation process?

Probe: a. What difficulties do you face when implementing the interventions?

11. How are the mine workers empowered to ensure implementation of interventions is done while working?

Implementation process

12. What plans are in place for monitoring and evaluation of the implementation process?
    Probes:
    a. How is the implementation monitored or evaluated?
    b. Why is the implementation process not working well?
    c. What steps do you carry out to ensure monitoring and evaluation of the implementation process are observed?
13. How do you report information from the monitoring and evaluation process?

Probe: a. The report generated how is it used for improving the implementation process?

14. What are your recommendations to ensure dust reduction in the mining industry?

Probe: a. What do you recommend to ensure government and other stakeholders are involved completely in ensuring dust reduction in the mining industry?

APPENDIX VIII: INTERVIEW GUIDE FOR UNION REPRESENTATIVES

Topic: Facilitators and Barriers influencing implementation of interventions to eliminate silicosis in the South African mining industry.

Background information

1. Please describe your role, position, and responsibilities with respect to occupational health in the mining industry?

Probes:

a. What is your area of expertise?

b. How long have you had this role?

c. What is your role with regard to the silicosis elimination programme in the mining industry?

Intervention characteristics

2. Describe the silicosis elimination intervention(s) you oversee or are involved in?

    Probe: a. How is the intervention being implemented?

3. How is the intervention implemented?

    Probes:

    a. What aspects of the intervention are working well?
    b. What aspects of the intervention are not working well?
    c. What is being done to address these challenges?
    d. In your opinion what do you think can be done to address these challenges?

Inner setting

4. How does the union assist in communicating the implementation of the interventions to mineworkers?

    Probes:

    a. To what extent do the union ensure mine workers' opinions are considered in implementing interventions for silicosis elimination?

b. What challenges do they face when communicating the implementation strategies?

5. What type of training programmes does the union organize to enable mine workers to perform their job and the implementation of the interventions?

   Probes:

   a. How well do you think the training prepared the mineworkers for the implementation process?
   b. What information or materials regarding the implementation process are available to the mineworkers?

Outer setting

6. In your opinion, what factors encourage the implementation of the interventions?

   Probes:

   a. To what extent have the government or the industry guidelines or policies influenced the implementation programme?
   b. What system is in place to ensure the mining industry comply with government policies on silicosis elimination?
   c. How are the policies and regulations on silica dust exposure limits enforced by the union?
   d. How does the "tripartite structure" contribute to the development of the interventions?
   e. What is the role of education, training, and awareness programme towards the implementation of the interventions?

7. In your opinion, what do you think stops the implementation of the interventions?

   Probes:

   a. How has the implementation of interventions affected the daily work routine of mineworkers?
   b. How have the following factors affected the implementation of the interventions negatively? (Availability of resources needed, Cost of the interventions, Management's commitment, Mineworker's opinion, complexity of the interventions, government policies and regulations).

8. What suggestions do you have to improve the implementation of the interventions?

Individuals involved

9. Who is involved in conducting the implementation process?
10. To what extent do you feel that the union has adequate knowledge about the implementation process?

    Probe: a. What are the attitudes and opinions of the mineworkers towards the implementation of the interventions to eliminate silicosis?

Implementation process

11. What plan is in place for monitoring and evaluation of the implementation process?
12. To what extent is the implementation process conducted according to plan?

    Probes:

    a. How frequent are the monitoring and evaluation done: yearly or quarterly?
    b. What difficulties do you face to ensure the implementation process is conducted as planned?

13. How do you report information from implementing the interventions?

    Probes:

    a. What challenges does the union face with respect to reporting?
    b. How can these challenges be tackled?

APPENDIX IX: INTERVIEW GUIDE FOR OCCUPATIONAL HYGIENIST AND OCCUPATIONAL MEDICAL PRACTITIONERS

Topic: Facilitators and Barriers influencing implementation of interventions to eliminate silicosis in the South African mining industry.

Background information

1. Please describe your role, position, and responsibilities with respect to occupational health in the mining industry?

   Probes:

   a. What is your area of expertise?

   b. How long have you had this role?

   c. What is your role with regard to the silicosis elimination programme in the mining industry?

Intervention characteristics

2. Describe the silicosis intervention(s) and elimination programme you oversee or are involved in?

   Probe: How is the intervention implemented?

3. What aspects of the intervention are working well?
4. What aspects of the intervention are not working well?
5. What is being done to address these challenges?

Inner setting

6. How is the implementation process communicated within the mining industry?
7. What kind of training do you think the mining industry needs to implement the interventions towards silicosis elimination?

   Probe: How well do you think the training they received prepared them well for the implementation process?

Outer setting

8. How are other countries implementing interventions for silicosis elimination?
   Probes:
   a. What is the success story of the other countries that are implementing interventions for silicosis?
   b. How is South Africa implementing interventions for silicosis elimination?
9. In your opinion, what factors encourage the implementation of the interventions?
   Probes:
   a. To what extent have the government or the industry guidelines or policies influenced the implementation programme?
   b. How does the "tripartite structure" contribute to the development of the interventions?
   c. How have the milestones targets been achieved through the implementation of the interventions for silicosis elimination?
   d. What is the role of education, training, and awareness programme towards the implementation of the interventions?
10. In your opinion, what do you think stops the implementation of the interventions?
    Probes:
    a. How have the following factors affected the implementation of the interventions negatively? (Availability of resources needed, Cost of the interventions, Management's commitment, Mineworker's opinion, complexity of the interventions, government policies and regulations).
    b. How have the government policies not helped in influencing the implementation programme?
11. What suggestions do you have to improve the implementation of the interventions?
12. What suggestions would help bring about dust reduction in the mining industry?
    Probes:
    a. What suggestions would help bring about the elimination of silicosis?
    a. What policies do you suggest that will assist in making the programme better?

Individuals involved

13. To what extent do you feel confident that the industry can conduct the implementation of the interventions?

Probe: a. To what extent do you feel that the workers have adequate knowledge about the implementation process?

Implementation process

14. What possible ways can the monitoring and evaluation of the implementation process be conducted?

    Probe: a. What can you highlight are the drawbacks to monitoring and evaluation of the implementation of the interventions?

15. How do you think the implementation process can be improved upon?

    Probes:

    a. How can the stakeholders assist in ensuring dust reduction?
    b. How can the stakeholders assist in ensuring the elimination of silicosis?

APPENDIX X: ETHICS CERTIFICATE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R49 Ms CJ Patrick

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M210638

NAME: **(Principal Investigator)**	Ms CJ Patrick
DEPARTMENT:	School of Public Health Division of Epidemiology and Biostatistics Medical School University
PROJECT TITLE:	*Facilitators and barriers influencing implementation of interventions to eliminate silicosis in the mining industry, Gauteng South Africa*
DATE CONSIDERED:	2021/06/25
DECISION:	Approved unconditionally
CONDITIONS:	
NOTE:	If contact information regarding student study participants is required, please contact the Registrar's office - <Nicoleen.Potgieter@wits.ac.za>
SUPERVISOR:	Drs N Ndlovu, O Ojifinni and V Govender
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2021/09/06

This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office secretariat on the 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **June** and therefore reports and re-certification will be due in the month of **June** each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

APPENDIX XI: CONTROLS FOR SILICOSIS ELIMINATION (MOSH, 2020)

The conveyor belt automated transfer point fogging dust suppression is a system with a moving belt that transfers the ores from point of collection to where it is to be used. While the conveyor is moving water droplets is increased and a liquid substance is also sprayed. The aim is to cause a binding effect on the ores and reduce the effect of RCS dust in the air. In addition, the water is treated with fungal and bacteria agents.

Scraper winch cover is used by the mineworkers during blasting in the mines to separate the ores from the rock. The scraper winch is fitted with a cover to reduce contact of the winch operator with dust particles.

Control Real-Time Monitoring (CRMT) is a system that assists in monitoring and giving information about engineering controls in real-time. The machine generates reports immediately in real-time as to where and when workers have been exposed to dust particles. The dust is not analysed but it indicates there is a need for immediate attention.

Footwall and sidewall treatment, here mineworkers spray water and surfactants on the footwalls and sidewalls of the mines to prevent dust particles in the air. Mostly, applied in underground mines where large respirable dust particles are released.

Fogger dust suppression system is a system that uses water to capture and suppress dust particles in the air during production.

In-stope atomisation for dust suppression, here RCS dust is prevented by spraying high fine droplets of water into the ventilating air to reduce exposure of mineworkers to the dust.

Multi stage filtration system, there are three stages in this system. What happens here is that the RCS dust in the air is extracted through a fan and then filtered. After filtrations the air released becomes decontaminated so that mineworkers are not exposed during operation.

APPENDIX XII: TURNITIN REPORT

TURNITIN REPORT CHINYELU PATRICK 1929376.docx

ORIGINALITY REPORT

5%	4%	3%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Gill Nelson. "Occupational respiratory diseases in the South African mining industry", Global Health Action, 2013 Publication	<1%
2	www.chamberofmines.org.za Internet Source	<1%
3	q10k.com Internet Source	<1%
4	www.saimm.co.za Internet Source	<1%
5	www.sec.gov Internet Source	A c hi e v
6	Derk H. Brouwer, David Rees. "Can the South African Milestones for Reducing Exposure to Respirable Crystalline Silica and Silicosis be	