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Occupational Noise-Induced Hearing Loss in South African Large Scale Mines: From policy formulation to implementation and monitoring



Nomfundo F. Moroe

Occupational Noise-Induced Hearing Loss in South African Large Scale Mines: From policy formulation to implementation and monitoring

NOMFUNDO F. MOROE

A RESEARCH THESIS SUBMITTED FOR THE DEGREEE OF

DOCTOR OF PHILOSOPHY IN AUDIOLOGY

IN THE FACULTY OF HUMANITIES

THE UNIVERSITY OF THE WITWATERSRAND

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DECLARATION

I, Nomfundo F. Moroe, hereby declare that this submission is my own original work and that the assistance which I received is detailed in the Acknowledgments of this report. To the best of my knowledge and belief, this work contains no material that has been accepted for the award of any other degree or diploma at any university or other institute of higher learning, except where due acknowledgement has been made in the text. I am responsible for the study and conclusions reached.



NOMFUNDO F. MOROE

23 day of October, 2018

ALL THE WAY MY SAVIOUR LEADS ME

All the way my Saviour leads me. What have I to ask beside?
Can I doubt His tender mercy, Who through life has been my Guide?
Heav'nly peace, divinest comfort, here by faith in Him to dwell!
For I know, whate'er befall me, Jesus doeth all things well.
For I know, whate'er befall me, Jesus doeth all things well.

All the way my Saviour leads me. Cheers each winding path I tread.
Gives me grace for every trial. Feeds me with the living Bread.
Though my weary steps may falter. And my soul athirst may be.
Gushing from the Rock before me, Lo! A spring of joy I see.
Gushing from the Rock before me, Lo! A spring of joy I see.

All the way my Saviour leads me. Oh, the fullness of His love!
Perfect rest to me is promised. In my Father's house above.
When my spirit, clothed immortal. Wings its flight to realms of day.
This my song through endless ages: Jesus led me all the way;
This my song through endless ages: Jesus led me all the way.

(Crosby, 1875)

DEDICATION

- To my mother, Thandekile Millicent Nzuza. At birth, you called me Nomfundo 'Mother of Education'. I can finally say I am living up to my name. Widowed at a young age, with eight children to raise and guide through life. You kept your head up through it all. Uwa uvuka nathi. Your sacrifices and love knew no boundaries. Words cannot capture the gratitude, admiration and the love I have you. Thank you Madam. Thank you Magutshwa. I could not have asked for a better mom.
- To my grandparents, Gideon and Pretty Simelane. Your prayers have carried me through life; from that little girl on your back to the woman I am today. I am, because you are. Thank you.
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- My friend, Zama Khumalo, for always listening to my endless complaints and fears. For reminding me, ever so often, that “nginguphunyuka bemphethe.” I guess she was right. Look at us now. God has been good to us friend. We have come so far, from small buckets to bottomless buckets.

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- **Moroe, N**. (2018). Hearing Conservation Programmes and Standards Threshold Shifts. Modikwa Platinum Health Clinic

STUDENT SUPERVISION

- Sibongiseni Mthiyane (2017). The Prevalence of otological symptoms in mine workers who are exposed to occupational noise in the workplace
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LIST OF ABBREVIATIONS

AIDS	Acquired Immunodeficiency Syndrome
dBA	Decibels A weighted
HCPs	Hearing conservation programmes
HPCSA	Health Professionals Council of South Africa
HIV	Human Immunodeficiency Virus.
HPDs	Hearing protection devices
ISO	International Organisation for Standardization
MHSC	Mine Health and Safety Council
NIHL	Noise Induced Hearing Loss
OHP	Occupational Health Professional
ONIHL	Occupational Noise induced hearing loss
PHL	Percentage of Hearing loss
PTS	Permanent Threshold Shift
RMA	Rand Mutual Assurance
SASOHN	South African Society of Occupational Health Nursing Practitioners
STS	Standard Threshold Shift
TTS	Temporary Threshold Shift
TWA	Time weighted average
TB	Tuberculosis

ABSTRACT

Purpose: The main objective of this study was to explore the management of occupational noise induced hearing loss (ONIHL) in the South African large-scale mines, from policy formulation to implementation and monitoring. Specific objectives included firstly reviewing current regulations, Acts, and policies regarding occupational noise-induced hearing loss in the South African mines. Secondly, establishing the extent to which these regulations, Acts and policies are observed, and/or implemented in hearing conservation programmes (HCPs) in South African mines. Thirdly, exploring factors influencing implementation of HCPs within the South African context. Lastly, exploring the role of audiologists in HCPs within the South African context.

Participants: Data were obtained from three sources. The first set of data were derived from six members of the Mine Health and Safety Council (MHSC) representing the State, Labour and the Employer; seven audiologists, two ventilation and occupational health engineers and one occupational hygienist. These participants were chosen from the websites of companies affiliated with the mining industry. Participants were contacted telephonically and via email to request their participation in the study.

The second source of data were obtained through document analysis of Acts, policies, regulations, and guidelines concerning occupational health and safety in the mining industry, particularly on ONIHL in the mining sector since 1994. These documents were selected through purposive sampling as it allowed the researcher to use data previously collected and readily available online. Websites of the companies affiliated with the mining industry were searched for the above-mentioned documents. This search yielded eight documents focusing on ONIHL and HCPs in the mining sector in South Africa.

Finally, data were collected from a systematic review of published studies on the management of ONIHL in the mining industry in Africa. This study utilised original pieces of scientific work and reports published in peer-reviewed scientific journals, conducted in the African mining sector between January 1994 and December 2016 and were published in English. These focused on the management of ONIHL in the mining sector in Africa. Various electronic bibliographic databases searched included Science Direct, PubMed, Scopus Medline, ProQuest and Google Scholar. The literature search yielded nine articles meeting inclusion criteria.

Design: The design used was a qualitative, cross sectional, non-experimental study, incorporating document analysis of policies, regulations, published articles, systematic review of literature and in-depth interviews with various stakeholders within the mining sector as well as a systematic review.

Data Analysis: A qualitative deductive content analysis approach was adopted for the current study. This allowed for a systematic and objective means to make valid inferences from verbal in-depth interviews with the stakeholders. It also allowed the use of written data from the analysis of Acts, policies, regulations, published studies and reports to describe the management of ONIHL within the South African mining sector.

Results: Findings of the current study revealed an overall lack of progress in minimising and/or eliminating ONIHL in South African mines. Based on the systematic review of literature on the management of ONIHL in the South African mining sector, current findings revealed that no single study has attempted to comprehensively or holistically address all the pillars of HCPs in the mining sector in South Africa. This was evidenced by the piecemeal fashion in which published studies post 1994 have been conducted; where individual pillars instead of comprehensive holistic HCP

have been targeted. Additionally, findings from these studies revealed only four pillars have been investigated in the last two decades.

Current findings also confirmed ONIHL remains a serious occupational health condition in South Africa. Such impairment interferes with quality of life and bears significant financial implications. This was revealed in stakeholders' views on the management of ONIHL in the South African mining sector. Factors such as lack of clearly defined action plans, as well as minimal collaboration among stakeholders were found to contribute to the failure of achieving desired outcomes in the elimination of ONIHL in the mining industry. Education and awareness training, as well as leading practice were highlighted factors contributing to progress in reducing ONIHL in the mining sector.

Findings from the analysis of policies, regulations and Acts revealed a flaw in the crafting, structuring and implementation of HCPs, particularly the 2003 and 2014 MHSC milestones on the elimination of ONIHL in the mining sector. These flaws speak to the fact that firstly, these targets focus upon only two aspects of noise conservation: hearing deterioration and noise source. Secondly, the sequencing of the milestones appears incongruent to the goal. Lastly, the time frame stipulated for reducing noise at the noise source increased from 5 years in 2003 to 8 years in 2014. Without a doubt, these flaws have an impact on achieving the desired outcomes.

Furthermore, in the South African mining sector, current findings have highlighted serious gaps in the role of occupational audiologists in the management of ONIHL and implementation of HCPs. Currently, occupational audiologists, whose scope of practice encompasses ONIHL, are minimally and peripherally involved in the development and execution of HCPs. Therefore, if this

situation is not properly addressed, may result in the continuing lack of progress towards the elimination of ONIHL.

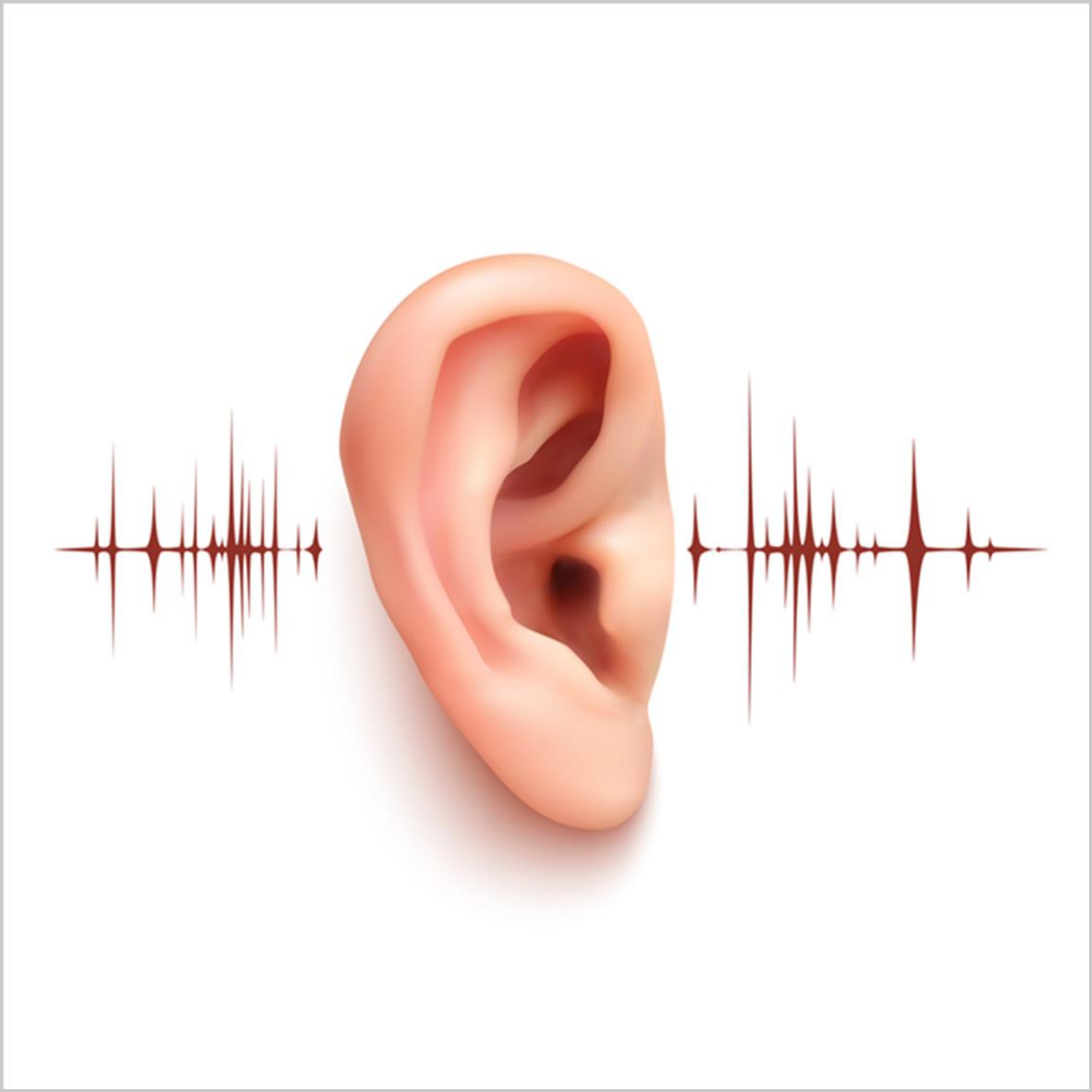
Lastly, the current study also revealed that access into the mining industry for research purposes is highly restricted. This has significant implications for objective and evidence-based HCPs in the South African mining industry.

Conclusions: Current findings attest to the complex nature of HCPs currently implemented in the South African mining industry. This author suggests HCPs should be viewed as complex interventions. Such a stance will assist in improving occupational health and safety at the individual, organisational, policy, and population levels of the mining industry. Therefore, as a way forward, the current study has successfully argued for HCPs to be viewed as complex interventions. Thereby, paving a way for mines to conduct realist reviews to better understand and contextual factors contributing to the successes and failures in implementing HCPs in the mining sector.

Furthermore, drawing from MHSC milestones on the elimination of ONIHL and the conceptual framework adopted in this study, an introduction of a feedback-based noise-monitoring model has been proposed as part of the current findings. Practically, this model can be used to estimate, monitor and provide quantitative information which can assist policy makers and mining administrators when making decisions regarding occupational health and safety in the mining industry. Thus, the impact of ONIHL in the mine could be reduced. Additionally, the model forms part of early intervention in the management of ONIHL in the workplace. This would result in significant savings in ONIHL compensation claims. As well, it would contribute to the quality of life of the people exposed to excessive noise in the workplace.

Key words: Access, Complex Interventions, Hearing Conservation Programmes, Mine Health and Safety, Mining Industry, Noise-monitoring tool, Occupational Audiology, Occupational Health and Safety, Occupational Noise Induced Hearing Loss, Policies, Realist Reviews, Stakeholders

CHAPTER 1. OCCUPATIONAL NOISE INDUCED HEARING LOSS INTRODUCED



No one needs to lose his or her hearing in order to earn a living. Noise-induced hearing loss is preventable (American Academy of Audiology, 2003)

Occupational Noise Induced Hearing Loss Introduced

Chapter 1 provides an overview of occupational noise induced hearing loss (ONIHL), as well as the statement problem, motivation, statement of originality, and the objectives of this study. Lastly, an overview of research methods and the overall outline of this thesis are presented in this chapter.

1.1 Background

The history of ONIHL dates as far back as 1886 when a British physician, Thomas Barr discovered the first scientific association between hearing loss and noise exposure in boilermakers in Glasgow (Azizi, 2010; Nair, 2014). Soon after, in 1890, Haberman contributed to the knowledge on ONIHL by highlighting the pathophysiology of ONIHL. Approximately five decades later, in 1939, Fowler described the characteristic noise-induced 4 kHz notch which is now considered a hallmark of noise induced hearing loss (NIHL) (Azizi, 2010). However, it was only in 1965 that ONIHL was recognized as an industrial medical condition in the United Kingdom. Subsequently, workers became eligible for compensation under the National Insurance Act (Nair, 2014). Since then, ONIHL has gained prominence globally as more cases of hearing loss were reported in industries prone to excessive noise. To name just a few, these include aviation, the military, construction, and mining (Nelson, Nelson, Concha-Barrientos, & Fingerhut, 2005)

ONIHL is an occupational medical condition (Lie, Skogstad, Johnsen, Engdahl, & Tambs, 2015) defined as a permanent sensorineural hearing loss caused by exposure to excessive levels of noise during the performance of one's occupation (Nelson et al., 2005; Thorne, 2006). Globally,

ONIHL is dubbed the number one work-related disability, and the second most common form of acquired hearing loss after presbycutic (age-related) hearing loss (Mostaghaci et al., 2013; Ritzel & McCrary-Quarles, 2008). Within the last decade, ONIHL has gained prominence as an important public health priority due to populations living longer and the spread of industrialization, thereby adding to the global burden of this affliction (Nandi & Dhatrak, 2008). Yongbing and Martin (2013) state that ONIHL is a potentially costly public health issue, especially in developing countries.

The presence of excessive noise in the workplace may result in individuals acquiring a disabling hearing loss, characterised by a hearing threshold below 40 dBs (Yadav, Yadav, Netterwala, Khan, & Desai, 2015), making it an invisible condition that does not readily manifest itself (Tye-Murray, 2009). Dugan (2003, p. 3) describes disabling hearing loss as the 'most prevalent, least recognised and least understood physical disability'. Additionally, Copley and Frederichs (2010) as well as Hermanus (2007) argue permanent disabling hearing loss is a major contributor to the global burden of disease for individuals, families, communities and countries.

The effects of incurring hearing loss in the workplace have adverse consequences on the health, safety, and economic outlook of the affected individuals, their families, societies and the state as well. For instance, sustaining a hearing loss in the workplace minimises possibilities and opportunities of further employment (Kane-Berman, 2017). Furthermore, a mild hearing loss may have a profound impact on the safety and work-related injuries for the affected individual (Amjad-Sardrudi, Dormohammadi, Golmohammadi, & Poorolajal, 2012). Moreover, prolonged exposure to hazardous noise in the workplace can potentially lead to increased fatigue and decreased concentration. This can ultimately lead to increased human errors (Amjad-Sardrudi et al., 2012; Picard et al., 2008). Additionally, excessive noise exposure can potentially reduce the worker's

ability to perform or complete tasks significantly dependent on auditory signals or verbal communication (Thorne, 2006). This subsequently results in a communication handicap, which ultimately, will affect teamwork and group productivity (Momm & Geiecker, n.d.).

According to Hong, Kerr, Poling, and Dhar (2013), the impact of ONIHL on one's health and quality of life cannot be quantified in tangible measures or standards. However, compensation costs for incidents of ONIHL are consistently increasing. For instance, the approximated total cost for occupational accidents and disease range between 1 and 3% of the Gross Domestic Product (GDP) in various countries (Rikhardsson, 2004). Statistics on the burden of ONIHL in developing countries are not readily available (Nelson et al., 2005); nevertheless, Chadambuka, Mususa, and Muteti (2013, p. 899) argue that 80% of individuals affected by ONIHL reside in low and middle income countries where ONIHL presents a "much heavier burden than in developed regions of the world". It is for this reason ONIHL is considered one of the greatest threats to a country's economy as well as public health.

1.2 **Statement of the Problem**

"South Africa's mining sector is controversial, exciting, empowering and a painful contradiction when seen through the eyes of the miner" (Teke, 2017, p. 1). In South Africa, the mining industry is one of the influential backbones supporting the country's political and economic growth. Economically, mining contributes a staggering R286 billion towards South Africa's GDP. Correspondingly, it is a major employer, creating 4.5 million jobs and contributes R10 billion to the fiscus annually through PAYE (pay as you earn) (Teke, 2017). It is also the largest contributor by value to Black Economic Empowerment in the South African economy as the majority of the

mine workforce is comprised of Black South African males (Worldwide Recruitment Solutions, 2014).

Politically, and historically, the mining sector has neglected the basic rights of most mineworkers. Hence, Teke's assertions "the mining industry in South Africa is a painful contradiction when seen through the eyes of a miner" (Teke, 2017, p. 1). Among the basics rights not observed by the mining industry is adequate occupational health and safety for miners (National Institute for Occupational Safety and Health [NIOSH], 1996). Consequently, the South African mining industry has been criticised for its poor health and safety as well as high numbers of fatalities (Cullinan, 2018; Nkosi, Claassen, & Voyi, 2015; Teke, 2017). Although there are reports indicating an improvement in this matter, injuries and fatalities remain high (Mining Review Africa, 2017).

ONIHL is an occupational health hazard and remains a prevalent condition in the South African mining industry (Edwards, Dekker, Franz, van Dyk, & Banyini, 2011; Kanji, Khoza-Shangase, & Ntlhakana, 2017; Ntlhakana, Kanji, & Khoza-Shangase, 2015; Strauss, Swanepoel, Becker , Eloff, & Hall, 2012; van Coller, 2015). Arguably, ONIHL is prevalent globally and millions of labourers around the world are affected by it (Kurmis & Apps, 2007; Le, Straatman, Lea, & Westerberg, 2017; Nelson et al., 2005; Sam, Anita, Hayati, Haslinda, & Lim, 2017; Win, Balalla, Lwin, & Lai, 2015). Even developed countries, such as America, (Concha-Barrientos, Campbell-Lendrum, & Steenland, 2004; Nelson et al., 2005; Suter, 2012; Tak, Davis, & Calvert, 2009), Europe (European Agency for Safety and Health at Work, 2005; Prasher et al., 2002), Australia (Australian Safety and Compensation Council, 2006; Safe Work Australia, 2010; Yamashita, Jiang, Le Prell, Schacht, & Miller, 2005) still report cases of ONIHL. However, there is evidence to suggest that in developed countries, the incidence of ONIHL is decreasing or at least

stabilising. This is attributed to advances in technology as most developed countries are now investing in quieter equipment and machinery in industries prone to excessive noise (Morata & Meinke, 2016; Safe Work Australia, 2010).

As stated earlier, the prevalence of ONIHL is high in the South African mining industry, consequently, this industry continues to be is criticised for poor health and safety standards. The prevalence of ONIHL in South Africa ought not be surprising, as South Africa is a developing country facing challenges associated with most developing countries. South Africa, as a developing country is faced with a greater burden of disease, increased unemployment rates, as well as political and economic instability (Gray & Vawda, 2016; Leboea, 2017; Lehohla, 2017). Perhaps, poor health and safety records reported in the mining sector, particularly ONIHL, may be contending with health conditions such as HIV/AIDS and tuberculosis - illnesses highly prevalent in the South African mining sector (Stuckler, Basu, McKee, & Lurie, 2011; Stuckler, Steele, Lurie, & Basu, 2013). However, neglecting ONIHL, which arguably, is not life threatening has economic effects such as poor job prospects and early retirement, thereby adding to the economic burden in a country already experiencing high volumes of unemployment (Leboea, 2017). Therefore, it is disquieting that despite mining in South Africa being one of the largest contributors to the economy it is also highly injurious to its labour force. Therefore, the constant presence of ONIHL merits research into this industry with an aim to identify practical and contextually evidence-based strategies to eliminate excessive noise in developing countries such as South Africa. Hence, this is the motivation for this study.

1.3 **Motivation for the Study**

The South African Mine Health and Safety Council (MHSC) states one of its goals as "every mine worker returning from work unharmed everyday: Striving for zero harm" (Mine Health and Safety Council, 2016). As far as ear and hearing health are concerned, this goal has not been realised despite the concerted efforts of the MHSC and the Chamber of Mines in South Africa (Booyens, 2013). The reality is, approximately 73.2% of miners in South Africa are exposed to excessive noise surpassing the legislated occupational exposure limit of 85 dBs, despite HCPs being implemented in the mining sector (Edwards et al., 2011; Strauss et al., 2012). Literature published on South African studies indicate HCPs are not successful in the mining industry. This is despite the concerted efforts made by the South African mining industry toward combating ONIHL in the mining industry. Since the declaration of the Mine Health and Safety Act of 1996 (President's office, 1996) researchers have evaluated the effectiveness and efficacy of the management of ONIHL within the South African mining industry (Edwards et al., 2011; Edwards, Milanzi, Khoza, Letsoalo, & Zungu, 2015; Edwards & Kritzinger, 2012; Kanji, Khoza-Shangase, & Ntlhakana, 2018; Ntlhakana et al., 2015; Strauss et al., 2012). These researchers have yielded findings indicating little, if any, success with HCPs.

For instance, Bomela (2005) conducted a study in a large South African Diamond mine, with a well-resourced HCP. The objective of this study was to establish whether there were additional cases of ONIHL in workers exposed to noise during the observation period of five years. Therefore, audiological records of 223 miners were reviewed over a 5-year period. Findings from this study indicated the HCP implemented at the studied mine was not effective as workers exposed to excessive noise presented with statistically significant incidence of ONIHL compared to the low exposure group, in the presence of a well-resourced HCP.

More recently, Ntlhakana et al. (2015) conducted a study in the gold and non-ferrous mining subsectors to explore the use of HPD in 90 mineworkers from two mines in Gauteng and Limpopo provinces. Interviews and direct observations were conducted on underground miners to ascertain if workers used hearing protection when working in noisy places. Findings of this study also confirmed the ineffectiveness of the HCP programme as far as the use of HPDs was concerned. Participants in this study reported inconsistently using HPDs; comfort, design, and work-related communication were identified as barriers to efficient and consistent use of HPDs. Reportedly, participants in this study were aware of the importance of protecting and preserving their hearing. However, according to the authors, this awareness was not motivation enough for them to use HPDs steadily (Ntlhakana et al., 2015). These findings highlight a need for more focused education on the impact and implications of exposure to hazardous noise levels in the workplace.

Another study was recently conducted to evaluate ONIHL awareness training programmes in six South African mines (Edwards et al., 2015). In this study, important awareness training challenges were identified. Firstly, there was a lack of prioritisation and commitment to awareness training in all the participating mines. Secondly, a large majority of the mines (80%) lacked a solid consolidated theoretical basis for their awareness training programmes. Thirdly, awareness-training programmes were conducted 30% in English only, 30% combined English and Zulu and 40% employee's language of choice. Lastly, findings from this study revealed 60% of the participating mines did not evaluate employees' knowledge post training.

Most recently Kanji et al. (2018) investigated South African mineworkers' knowledge regarding NIHL. This study revealed that the majority of the participants were aware of the negative consequences of exposure to noise on their hearing function in the workplace. However, the findings indicated superficial coverage of content, as the mineworkers were not aware of the

type of noise they were exposed to nor the impact of prolonged exposure to noise in the workplace. Furthermore, more than 50% of the participants in this study reported inconsistent use of HPDs when exposed to noise in the workplace. Therefore, this study confirmed ONIHL in the mining sector remains a serious occupational health concern with severe financial and quality of life consequences. Thus, the authors argue that, for HCPs to be successful there is a need for comprehensive, systematic and individualised education and training programmes on noise exposure and its effects on hearing. Although this study provided evidence regarding the shortcomings of HCPs in the South African mining industry, these findings should be interpreted with caution due to the study's small sample size. This was also acknowledged by the authors.

Based on the above studies, it is clear the South African mining industry is not making desired progress in the management ONIHL in this sector. This lack of progress in the success of HCPs was also echoed by the chairperson of the Mining Lekgotla (Council), who lamented ONIHL "is prominent in the mining industry because action plans aimed at eradicating this disease are not as well integrated as they should be. We need far more comprehensive noise-control programmes. The Chamber of Mines is not making the desired progress with noise-induced hearing loss, which is a major occupational health concern. However, the industry itself is committed to the massive reduction and elimination of ONIHL" (Booyens, 2013, p. 1).

Literature suggests that the success of HCPs is heavily dependent on adhering to all HCP pillars (Amedofu, 2007; Hong et al., 2013). These pillars include periodic noise exposure monitoring, engineering controls; administrative controls, personal hearing protection, audiometric evaluations, employee/management education and training, as well as record keeping (Amedofu, 2007; Hong et al., 2013). Studies reviewed in this thesis, including studies mentioned above often focus on a specific pillar within the HCP and not comprehensively on all pillars of

HCPs. For instance, Bomela (2005) focused on audiometric evaluations, Ntlhakana et al. (2015) focused on the use of HPDs, while Edwards et al. (2015) as well as Kanji Kanji et al. (2018) focused on education and training. Omitting or neglecting some pillars of the programme will potentially lead to the failure of the programme, as all aspects are necessary and play an important role in the effectiveness of the conservation programme. Therefore, there is a need for studies to engage and interrogate in detail all aspects of HCPs, as they are fundamental to the success of eradicating ONIHL in the South African mining sector. Furthermore, literature acknowledges that even though HPDs are the least effective as compliance is very low, they are the most used method of noise reduction (Ntlhakana et al., 2015; Patel et al., 2010; Steenkamp, 2003). A study conducted by Patel et al. (2010) indicated that miners do not fully comprehend the impact and the lifelong effects of being exposed to high levels of noise in the work place. Hence, the low levels of compliance in the use of HPDs. Patel's study highlighted the need for education and training for miners. In the South African mining industry, Kanji et al. (2018) and Edwards et al. (2015) also echoed the importance of educating in reducing or possibly eliminating the prevalence of ONIHL in the mining sector.

Finally, yet importantly, the role of audiologists in the mining industry has not received much attention. According to the American Academy of Audiology (1997), audiologists should be the principal advocates for and the supervisors of HCPs. However, the American Academy of Audiology (1997) reports few audiologists serve as consultants in the mining industry. Moreover, even fewer are involved in noise measurements, training of occupational hearing conservationists, HCP audits or programme evaluations.

This American position seems to mirror the South African context, as there is a paucity of research on the involvement of audiologists in the formulation of policies related to the

management of noise in the workplace within the South African context. It is this researcher's view that audiologists have an important role to play in informing policy makers about the effects of hearing loss. Not just the immediate effects, but also long-term effects of exposure to noise and the quality of life of the people exposed to this noise. Furthermore, audiologists can play a crucial role in informing policy makers on issues such as otoprotective drugs, which are currently on trial internationally (Campbell & Le Prell, 2011; Cascella et al., 2012; Gilles, Ihtijarevic, Wouters, & Van de Heyning, 2014). Audiologists can provide evidence-based recommendations to advocate for the routine use of otoprotective drugs for miners exposed to high levels of noise. Therefore, establishing the status of ONIHL and its management in developing countries becomes important if strategic planning around this occupational health challenge is to be systematic, comprehensive, and successful. Consequently, this study was conceptualized with this backdrop in mind. The current study, therefore aimed to be comprehensive in its approach in exploring the management of ONIHL in the South African large-scale mines from policy formulation to implementation and monitoring. Several other studies have focused on identifying barriers jeopardising the success of HCPs in South Africa. However, the current researcher believes these studies will continue to yield the same unsatisfactory results unless careful, strategic and contextually relevant changes adopting realist reviews within a complex intervention position are considered.

There is a need for new, innovative and evidence-based ways of managing excessive exposure to hazardous noise in the mining industry. These approaches must be devised to focus on holistically understanding why HCPs are not successful in the South African mining industry while their counterparts in developed countries have reported success. A holistic investigation implies a detailed, in-depth review of policies and regulations concerned with the well-being of the

mineworkers who are exposed to excessive levels of noise in the workplace. As well, it must take into account the perspectives and views of the various stakeholders on the management of ONIHL.

1.4 **Statement of Originality**

The distress call from the Mining Lekgotla chairperson for more comprehensive noise-control programmes presented an opportunity for this study aimed at exploring the management of ONIHL in the South African mining sector from policy formulation to implementation and monitoring.

Literature review revealed that no study has explored the management of ONIHL from policy formation to implementation and monitoring in the South African mining sector. The researcher believes that to fully appreciate true nature and status of HCPs implemented in the mining industry and to address all the reported challenges with the management of ONIHL, it is diagnostic to carefully examine the processes that informed the conceptualization of the policies, goals objectives and expected outcomes. To examine these processes, it is imperative to identify the various stakeholders who have participated at any stage of the process, as well as their roles in the process. Additionally, it is important to understand how the set goals, objectives, and expected outcomes of the mining industry are translated and delivered to the ultimate stakeholders, the mineworkers – the individuals directly and physically affected by excessive noise exposure in the workplace. Hence, the importance of the current study.

To contextually understand the factors influencing the implementation of HCPs in the South African mining industry, there is need to consider and define HCPs as complex interventions. Complex interventions are defined as interventions built from multiple interacting components, which may act both independently and interdependently (Medical Research Council,

2000; Moore et al., 2015). These interacting components may include behaviours, behaviour parameters and methods of organizing those behaviours; and they may have an effect at individual, organizational or population level (Datta & Petticrew, 2013; Medical Research Council, 2000; Moore et al., 2015; Pawson, Greenhalgh, Harvey, & Walshe, 2005). Furthermore, complex interventions serve as a springboard for organisations to conduct realist reviews.

A realist review is an evaluation approach fundamentally concerned with "understanding and unpacking the mechanisms by which an intervention works (or fails to work)" (Rycroft-Malone et al., 2012, p. 1), by taking into account the context to methodically and transparently synthesizing data.

Pawson et al. (2005) state that a realist review provides stakeholders and policymakers with enlightenment and empirical evidence on the nature of the programme or intervention implemented in a given setting. Secondly, a realist review assists policymakers interpret and clearly understand why a programme worked better in one context than another. Thirdly, a realist review provides policymakers with justification for taking one course of action over another. Fourthly, a realist review alerts policymakers to potential problems and specific measures that can be applied to mitigate potential problems. Lastly, a realist review is explanatory rather than judgmental in nature (Pawson et al., 2005).

In collecting and analysing data for the current study, the researcher identified a gap in that HCPs, which aptly fit the above-mentioned definition of complex interventions, are not defined as complex interventions, thereby, eliminating the possibility of conducting realist reviews in the South African mining sector. Therefore, the researcher took the opportunity to argue for the recognition of HCPs as complex interventions. The researcher believes realist reviews are the most suited and effective method of evaluating HCPs in the mining sector as they, in explaining what

works and how, take into account the context of each setting without being judgmental (Pawson et al., 2005). Recognising and defining HCPs as complex interventions will pave the way for contextually evidence-based studies to be conducted in South Africa's mining industry.

Furthermore, in analysing policies related to ONIHL – particularly the 2003 and 2014 Mine Health and Safety milestones (MHSC, 2014b), flaws were identified in the crafting, structuring and implementation of these milestones.

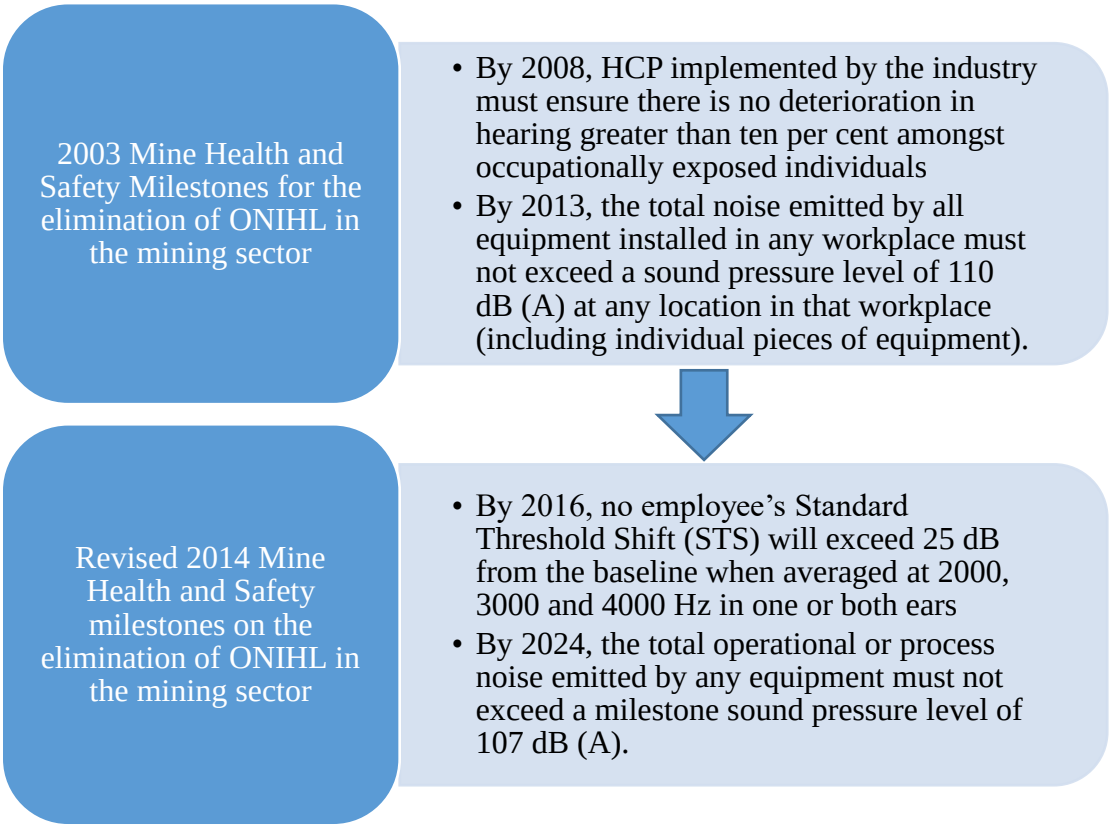


Figure 1: - 2003 and 2014 MHSC milestones on ONIHL in the South African mining industry.

In reviewing the milestones in Figure 1 above, the following flaws were noted: Firstly, the set targets focus on only two aspects of noise conservation – hearing deterioration and noise source.

These two aspects fall under the responsibility of mine management. A key stakeholder in this process, the mineworker, has been excluded in the setting of the targets. Secondly, the sequencing of the two targets – hearing deterioration and noise source – appears incongruent to the goal. Reduction of noise from the noise source should come prior to the expectation of reducing the deterioration of hearing loss as noise is the precursor to hearing loss in this context. These milestones, as currently stated, appear to expect the opposite. That is, there must be a reduction in deterioration of hearing loss in miners at least 5 to 8 years before the reduction in the intensity level of noise sources causing hearing loss. Lastly, the 2014 milestone revisions do acknowledge the industry's failure to meet the 2003 milestones. However, these same revisions have increased the timeframe for reducing noise from the noise source from 5 to 8 years. This seems to indicate serious shortcomings with this target.

Therefore, bearing in mind the identified gaps in the MHSC 2003/2014 ONIHL milestones, the researcher, adapted the Risk Management Framework (Comcover, 2016), to developed a noise management matrix. This noise management matrix is a feedback-based model for monitoring ONIHL in the mining sector. This matrix was converted to a basic static feedback model with practical applications such as estimating, monitoring and providing quantitative information to aid miners, mining administrators and policy makers in decision-making around HCPs. Such methodology has great potential for reducing the impact of ONIHL in the mines. Additionally, the model could form part of early intervention and management of ONIHL in the workplace. The strength of this model, although currently static, is it encompasses all the pillars of HCPs. Moreover, it takes into account the policies concerned with the management of ONIHL in the mining sector.

Last, but not least, as referred to earlier, the role of audiologists in the mining industry has not been given much attention. As such, there is dearth of literature both locally and internationally on the active role of audiologists in the management of ONIHL. Consequently, this study also explored the role of occupational audiologists in order to understand their level of involvement or non-involvement. Occupational audiologists – who are experts in the management of ONIHL, are seemingly not actively involved in their role as outlined in their scope of practice. Therefore, this study argued for the involvement of occupational audiologists in the management of ONIHL, from policy formulation to the implementations, monitoring and evaluation of HCPs in occupations prone to excessive noise.

1.5 **Conceptual framework**

The current study applied the Risk Management Framework (RMF) in the management of ONIHL in the mining sector in South Africa (Figure: 2).

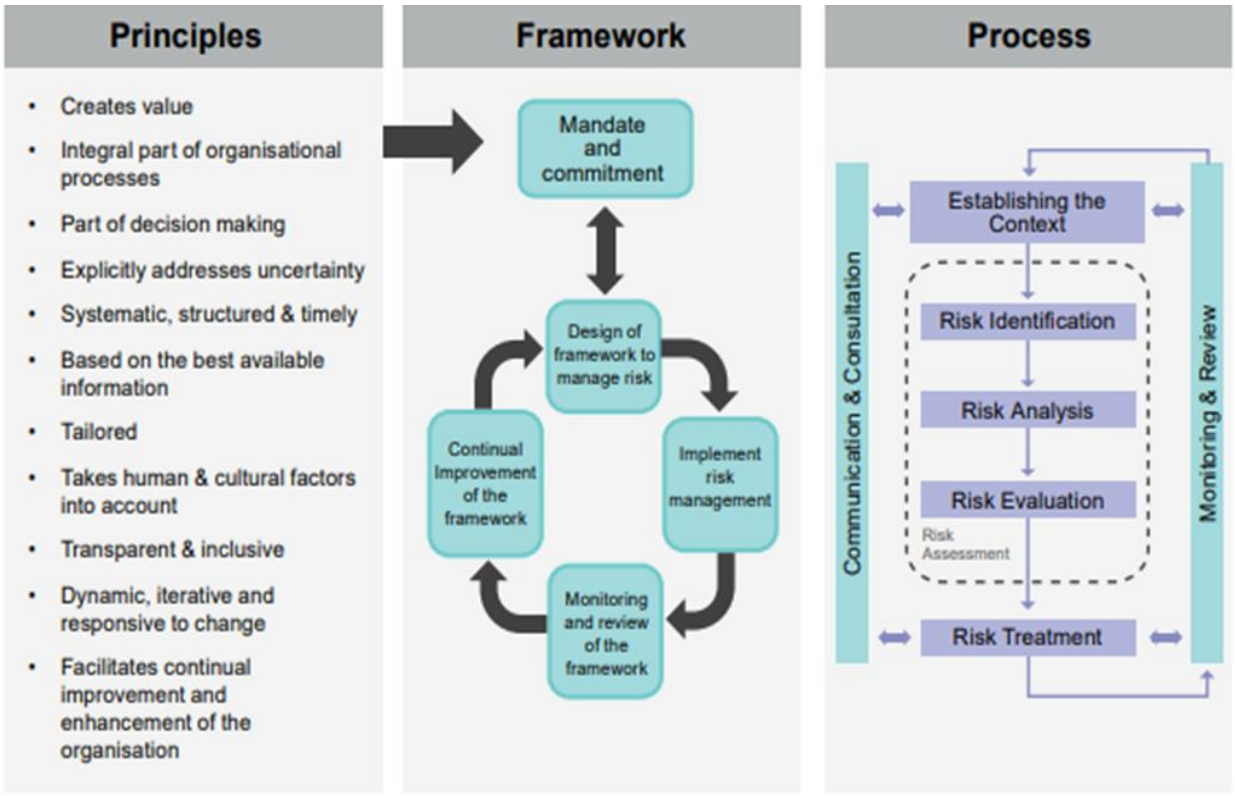


Figure 2: - Risk Management Framework

Source:(Comcover, 2016)

The Risk Management Framework adapted from ISO 31000 (AIRMIC, 2010) and revised by the Australian Government's Department of Finance Comcover (2016) was adopted as a conceptual framework for this study. Fiedler (2004) postulates many workplaces have hazards. That is, anything presenting a threat to health and safety within an organisation, which may put employees at risk of injury or harm to health, thereby necessitating systematic management such a Risk Management Matrix. Risk matrices have been used for years to rank various risks in the military (Donoghue, 2001). More recently, practitioners, academics and the business community have

shown an interest in risk management (Dabari & Saidin, 2014). Risk management has become a primary goal in every organisation due to its ability to promote organisational outputs and create measureable value for stakeholders (Gates, Nicolas, & Walker, 2012).

Relating to occupational health and safety, Hermanus (2007, p. 536) argues "the underlying premise of risk management is that improvements in health and safety can be made by correctly identifying and addressing hazards or factors (which may be underlying or direct) that contribute to occupational risk". Hence, the value of the current study. Fiedler (2004) compliments this argument by stating risk management is an integral and critical factor in the success of occupational health and safety in that, it serves to identify and assess risks resulting from hazards. This consequently leads to appropriate action to reduce or eliminate risk (Fiedler, 2004). Comcover (2016) argues if ISO 31 000 RMF is consistently implemented, risks are identified, analysed, evaluated and managed in a uniform and focused manner. As such, Comcover (2016, p. 1) states three crucial and core components that need to be implemented consistently in order to achieve a structured approach to the management of risk as depicted in Figure: 2).

- a set of principles to describe the essential attributes of good risk management;
- a risk management framework providing a structure for risk management; and
- a risk management process which prescribes a tailored, structured approach to understanding, communicating and managing risk in practice.

Therefore, drawing from the discussion above, this study was premised under the RMF as it sought to explore the management of ONIHL in the mining sector South Africa. In line with the RMF, exposure to excessive noise was deemed a hazard and the resultant ONIHL, as a risk, needing to be analysed and managed. This study landed itself within the RMF in that it aimed to explore the

management of ONIHL in the South African mining sector from policy formulation to implementation and monitoring. This required the current study to take the following into account:

- the principles on which the objectives of the mining industry are anchored,
- to explore the risk management framework,
- to interrogate the risk management processes currently implemented in the mining industry.

1.6 **Research Aims and objectives**

The rationale and theoretical framework of this study draws from the backdrop of ONIHL in the South African mining sector. This study's primary aim was to explore the management of ONIHL in large-scale South African mines, from policy formulation to implementation and monitoring. It has been established that ONIHL has adverse and permanent consequences on affected individuals, their families, society and the country at large. Thus, there is more than enough merit for further investigation into the more practical and effective strategies to curb or possibly eradicate ONIHL in the mining industry.

ONIHL affects the worker's health, occupational performance, and other job opportunities, thereby contributing to economic problems in a country already laden with the heavy burden of disease and unemployment. Conducting this study to explore the management of ONIHL in the mining sector from policy formation to HCPs implementation, monitoring and evaluation was guided by the following objectives:

- To review current regulations, Acts, and policies regarding occupational noise-induced hearing loss in South African mines
- To establish the extent to which the above are observed, and/or implemented in HCPs in South African mines

- To explore factors influencing implementation of HCPs within this context
- To explore the role of audiologists in HCPs within this context

The above-mentioned objectives led to the research questions presented below.

1.7 Research Questions

- What are the current regulations, Acts, and policies regarding occupational noise-induced hearing loss in the South African mining industry?
- To what extent are the above observed and/or implemented in the in HCPs in South African mines?
- What are the factors influencing the implementation of HCPs within this context?
- What is the role of audiologists in HCPs within this context?

1.8 Overview of Research Methods

All the manuscripts included in this study have detailed methodological sections. Therefore, a brief outline of the methods used in this study as well as other relevant information not included in those articles due to space constraints are discussed in this section.

1.8.1 Research Design

In order to answer the predefined research questions of the current study, a qualitative approach was adopted. This methodology was chosen to accurately capture and describe the management of ONIHL in the South African mining industry as a phenomenon under study. In line with the assertion by Anderson (2010, p. 1) "qualitative research is useful to policymakers because it often describes the settings in which policies will be implemented".

One aspect of this study was concerned with policy formulation on the management on ONIHL. It was also anticipated that findings from this study would provide policymakers and various stakeholders with valuable information to consider when engaging in policies. Furthermore, this study sought to explore the perspectives of various stakeholders. Therefore, qualitative research was chosen as it yields thick and detailed descriptions of participants' feelings, opinions, and experiences. It also allows for interpretation of participants' actions (Rahman, 2017). Lastly, data for this study was collected through document analysis and in-depth interviews. Consequently, qualitative research was employed as it was deemed most appropriate (Anderson, 2010).

Part of this study focused on reviewing policies, Acts and regulations on the management of ONIHL. As well, a systematic review of published literature on the management of ONIHL in the mining sector in Africa was performed. Therefore, in addressing this aspect of the study, Document Analysis (DA) was conducted. (DA) is a qualitative, systematic approach employed to evaluate printed and electronic documents with an aim to obtain meaning and understanding as well as to develop empirical research (Bowen, 2009; Corbin & Strauss, 2008).

DA involves thorough examination and interpretation of data to "elicit meaning, gain understanding and develop empirical knowledge" (Bowen, 2009, p. 27). In line with the characteristics of DA as discussed by Bowen (2009), DA, in this study served as a base for developing interview questions for stakeholders who participated in this study. Furthermore, DA provided a means for tracking changes and new developments, as well as verify findings or corroborate evidence from other sources, such as the stakeholders who participated in this study. It provided information on events stakeholders may have forgotten as well as background and context on the policies currently in place for the management of ONHL in the mining sector. Lastly, it provided a trail of published studies on the management of ONIHL in the mining sector

which were analysed in a systematic review to record the current trend in the management of ONIHL in the African mining sector.

In-depth interviews were also incorporated to explore perspectives of various stakeholders on the management of ONIHL in the South African mining sector. In line with qualitative research which seeks to uncover existing truths and develop a thorough understanding of reality as well as the individual's perception of what is real (Williamson, 2009), in-depth interviews were conducted. Views and perspectives of stakeholders served to bring to the fore contextual truths and knowledge regarding management of ONIHL in the mining sector. These participants were well suited to respond to questions posed to them regarding ONIHL in the mining sector. This was due to the fact they possess contextual knowledge and experience regarding the failures and successes made toward achieving the goal of zero harm as stipulated by the MHSC.

1.8.2 Sampling Strategy

A purposive sampling was utilised in this study as it allowed the researcher to identify suitable participants. This also allowed using data previously collected and readily available to the researcher. This greatly assisted this researcher in conducting document analysis and a systematic review of literature on the management of ONIHL in the mining sector.

Data were obtained from three sources: interviews with the stakeholders in the South African mining sector, document analysis of the regulations on ONIHL in the South African mines and lastly, literature review of original research on the management of ONIHL in the mining sector. Therefore, the use of purposive sampling was ideal in that, according to Etikan, Musa, and Alkassim (2016) purposive sampling allows a researcher to identify and select individuals or

groups of individuals who have experience and are knowledgeable on the phenomenon under investigation. In this case, knowledgeable stakeholders who are well versed in the management of ONIHL in the mining industry. Furthermore, the researcher sough to recruit participants who are available and willing to participate in the current study as well as access documents and original research studies that are readily available online.

1.8.3 Sources of Data

Interviews with various stakeholders

For this study, the aim was to gather contextually relevant and insightful information on the management of ONIHL in the South African mining sector. Therefore, the researcher predefined various stakeholders as suitable potential participants for this study. The following stakeholders were purposively included in the study:

- Mine Health and Safety Council (MHSC) - key stakeholders in formulating and publicising policies, regulations and Acts on occupational health and safety, including the management of ONIHL. The MHSC is comprised of representatives from the State (the Department of Mineral Resources), the Employer (various mining houses and the Chamber of Mines) as well as Labour (the numerous unions).
- Occupational health and safety officers, occupational hygienists and audiologists - stakeholders in the management of ONIHL as they are generally in direct contact with individuals exposed to excessive noise. Therefore, they are tasked with implementing and monitoring HCPs carried out in the mines.

Due to difficulties experienced by this researcher in recruiting participants, in conjunction with purposive sampling, snowball sampling was also utilised to expand the pool of possible

participants for this study. Snowball sampling was particularly important in that suitable stakeholders such as occupational audiologists and occupational hygienist are scarce and not easily located in the South African context. Therefore, the researcher took advantage of the social networks of identified participants to create an expanded set of potential participants, thereby allowing a series of referrals to be made within a circle of acquaintances (Atkinson & Flint, 2001).

Participants were identified from the websites of the companies affiliated with the mining industry and were subsequently contacted telephonically and via email to request their participation in the study. The interviews were conducted both face-to face and telephonically, depending on the availability of participants. The researcher formulated the interview questions for stakeholders and audiologists (Appendix A and B). Questions focused on the specific roles of the participants, the objectives of the mining industry with regard to the management of ONIHL, as well as the challenges and progress made since the formulation of evaluation of the HCPs in the mining sector.

Document Analysis

The second set of data was obtained through the document analysis of the Acts, regulations, policies, and guidelines on ONIHL management in the South African mining sector since 1994. Company websites affiliated with the mining industry were searched for the above-mentioned documents. The search yielded eight documents which accurately focused upon occupational health and safety – particularly ONIHL in the mining sector. Access to company-specific documents was restricted to company members or staff. Therefore, document analysis was conducted using policies on occupational health and safety available online. In hindsight, the exclusion of company-specific documents aided in eliminating any bias that may have resulted by using information obtained via company-specific documents. Documents included and analysed

in this study dated from 1994 to the present with a focus on occupational health and safety in the South African mining industry.

Systematic Review

The last set of data was obtained from a systematic literature review of the management of ONIHL in the African mining industry. A methodical evaluation of the literature was conducted in line with the Cochrane Collaboration guidelines in conjunction with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Higgins & Green, 2011; Moher, Liberati, Tetzlaff, & Altman, 2009). Electronic bibliographic databases searched included Science Direct, PubMed, Scopus Medline, ProQuest and Google Scholar. The search terms utilised (PubMed Mesh terms) included "occupational noise induced hearing loss", "occupational noise AND hearing loss", "work- related noise" OR "hearing loss" OR "hearing impairment" OR "disability", "noise in the workplace" AND "Africa" OR "African" OR "sub-Saharan Africa" AND "management" OR "managing" OR manag* "addressing" OR "intervention" AND 'mining" "min*".

Included in this study are original pieces of scientific work or reports published in English and in peer-reviewed scientific journals as well as articles/reports conducted in the African mining sector between January 1994 and December 2016. The focus was on management of ONIHL in the mining sector in Africa. The literature search yielded nine articles meeting the inclusion criteria.

1.8.4 Ethical Considerations

All procedures contributing to this work adhered to the standards of the relevant national and institutional guidelines on human subjects for research purposes. Therefore, this study adhered to the Helsinki Declaration of 1975 as revised in 2008 (World Medical Association, 2008).Prior to commencing with this study, approval was obtained from the Human Research Ethics committee

(Medical) of the University of the Witwatersrand (Protocol number: M160264) (Appendix E). Furthermore, stakeholders were provided with information letters (Appendix F). Ethical aspects such as confidentiality and the right to withdraw from the study were discussed with the participants. Anonymity however, was not guaranteed as snowball sampling was utilised in this study. However, the participants were made fully aware all information given to the researcher would be kept confidential.

1.9 Outline of the Thesis

Chapter 1: Background

This chapter provided a brief overview of ONIHL and its effects, both on the individual and the economy. Moreover, it outlined the problem statement as well as the rationale for this study. Additionally, the aims, objectives and research questions for the current study were presented. Lastly, this chapter also provided an overview of the methods used in the study, as well as the outline of all chapters in this thesis.

Chapter 2: Literature Review

This chapter provides a comprehensive and critical review of relevant literature and locates this study in relation to existing published work.

Chapter 3: Paper I: Research into Occupational Noise induced Hearing Loss in South African large-scale mines: Access Denied?

This paper investigated the feasibility of conducting audiological research into ONIHL within the South African mining sector. Specific objectives involved determining ease of identifying focal

persons in charge of HCPs; establishing response time and rate of each identified focal person for interviews; and exploring focal person's willingness to share information regarding HCP.

Chapter 4: Paper II: The management of occupational noise induced hearing loss in the mining sector in Africa: A systematic review- 1994 to 2016

Through a systematic review of literature, this paper explored and documented current evidence reflecting trends in the management of ONIHL in the mining industry in Africa from 1994 to 2016.

Chapter 5: Paper III: Management of Occupational Noise Induced Hearing Loss in the South African Mining Sector: A View from the Top

This paper explored the views of various stakeholders on the formulation, implementation, monitoring and evaluation of the Mine Health and Safety Councils (MHSC) 2003 and 2014 ONIHL milestones.

Chapter 6: Paper IV: Management of occupational noise-induced hearing loss in the mining sector in South Africa: Where are the audiologists?

This paper explored the scope of practice for occupational audiologists in the mining industry as well as the audiologists' involvement in HCPs in South African mines. Additionally, this paper investigated the mining industry's role in the audiologists' involvement. It also established audiologists' levels of preparedness for 'real life' work in occupational audiology in the South African context.

Chapter 7: Paper V: Occupational noise induced hearing loss in South African large-scale mines: Exploring Hearing Conservation Programmes as Complex Interventions embedded in a Realist Approach

This paper argued for the recognition of HCPs as complex interventions, in order to pursue innovative approaches such as realist reviews. Realist reviews provide contextually relevant evidence- based information which can be used to explain success and/or failure of HCPs in a given context at any given point in time.

Chapter 8: Paper VI: A Feedback-Based Noise-Monitoring Model: A Proposed Model of Managing Occupational Noise Induced Hearing Loss in the Mining Sector in South Africa.

This paper introduces a feedback-based noise-monitoring model as a tool to manage exposure to noise. This feedback-based model is based on a noise management matrix adapted from a risk management matrix. This model can be implemented to enhance efficiency and effectiveness of HCPs currently implemented to avoid negative consequences of ONIHL.

Chapter 9: Synthesis of the findings

This chapter synthesises chapters 3 to 8 and demonstrates how these combined chapters add to the body of knowledge in the field of occupational audiology. Furthermore, this chapter offers a reflection on the research process. It also identifies study design and methodology limitations and raises implications for theory and practice in this field while offering recommendations for future directions.

1.10 Roles and Responsibilities

The researcher, in consultation with the supervisor conceptualised the study. The researcher also drafted and submitted a PhD proposal, which was approved by the University's Human Research

Ethics committee (Medical). During its conceptualisation stage, this study was supported by the Thuthuka Post-PhD Track Grant (TTK1206131255), which was obtained by the supervisor.

Thereafter, the researcher secured funding from NRF-Research Development Grant, the Consortium for Advanced Research Training in Africa (CARTA) as well as NRF- Thuthuka PhD Track. Upon approval from the Ethics Committee (Appendix C), the researcher, as the primary and sole investigator collected and analysed all data for this study. Data were collected over a period of 18 months. As presented in the publications section, the researcher was the sole author for all submitted manuscripts. The role of primary researcher included making substantial contribution in conceptualising, data collection and analysis as well as writing all manuscripts. These were then submitted to the supervisor for critical theoretical and technical feedback. Based on the feedback received from the supervisor, necessary corrections were made to the supervisor's satisfaction. The researcher also identified, submitted, and corresponded with all relevant journals and engaged in all necessary revisions of the manuscripts.

CHAPTER 2. OCCUPATIONAL NOISE INDUCED HEARING LOSS



"Hearing is the soul of knowledge and information of a high order. To be cut off from hearing is to be isolated indeed." Helen Keller

Occupational Noise Induced Hearing Loss

This chapter provides an overview of ONIHL focusing on its prevalence, risk factors, socio-economic factors and management. Furthermore, to orient the reader, this chapter briefly provides context to the South African mining industry.

2.1 Occupational Noise Induced Hearing Loss

Generally, literature defines ONIHL as a sensorineural partial or complete loss of hearing developing gradually over a period of several years due to exposure to continuous or intermittent high levels of noise at levels above 85dBA during an 8-hour workday in the workplace (Krishnamurti, 2009; McBride, 2004; Nandi & Dhatrak, 2008; Patel et al., 2010; Rappaport & Provencal, 2001).

However, this definition is misleading as it assumes ONIHL is always sensorineural in nature. Sufficient evidence exists to dispute this fact as ONIHL can be conductive or mixed in nature. According to Yong and Wang (2015) for instance, there are two ways in which individuals can sustain ONIHL. The first way is through an acute acoustic trauma resulting from exposure to intense impulse noise from 100 to 150 dBs sound pressure level over a relatively short duration of exposure (Choi, 2012; Yong & Wang, 2015). Such intense noise impulses can cause delicate inner ear tissues to stretch beyond their elastic limits (Yong & Wang, 2015), thereby resulting in a conductive hearing loss (Choi, 2012). This is due to damage to the tympanic membrane, which may gradually progress to a mixed or sensorineural hearing loss depending on the sustained injury and recovery process. This type of ONIHL often results in an immediate and permanent hearing loss. Acute acoustic trauma is common in occupations such as the military due to gunshots, jet

engines or explosions near unprotected ears, to name only a few (Bonfort et al., 2014; Medina-Garin et al., 2016; Rezaee, Mojtahed, Ghasemi, & Saedi, 2012; Yong & Wang, 2015).

The second and most common way of sustaining ONIHL is through exposure to long term, low level noise which damages the cochlear metabolically as opposed to mechanically (Yong & Wang, 2015). In the exclusion of any acoustic trauma to the ear, this kind of hearing loss is sensorineural in nature. It can be partial or complete and develops gradually over a period of several years. This type of loss is a consequence of exposure to either continuous or intermittent high levels of noise at levels above 85 dBs (A) during an 8 hour shift in the workplace (Alabdulwahhab et al., 2016; Friis, 2016; Krishnamurti, 2009; McBride, 2004; Nandi & Dhatrak, 2008; Patel et al., 2010; Rappaport & Provencal, 2001). As demonstrated above, acute acoustic trauma and chronic exposure to excessive noise may result in ONIHL. Therefore, for the purpose of this study, the latter definition will be applicable as this study is concerned with ONIHL due chronic exposure to excessive noise over an extended period of time in the workplace. ONIHL is said to be more prevalent in males because, historically, industries such as agriculture, mining, construction, manufacturing, transportation, and the military are dominated by males (Hong et al., 2013; Nandi & Dhatrak, 2008; Pratt et al., 2009; Singh & Bhardwaj, 2013).

2.2 **Prevalence of Occupational Noise Induced Hearing Loss**

ONIHL is a prevalent condition globally and is classified as the number one work-related disability. It is the second most common form of acquired hearing loss after presbycutic (age-related) hearing loss. Older people with presbycutic hearing loss suffer even more severe consequences if they have been exposed to high levels of noise during their work life (Mostaghaci

et al., 2013; Ritzel & McCrary-Quarles, 2008). This is particularly so in developing countries (Chadambuka et al., 2013; Miah, Rubya, & Kabir, 2014).

In 1995, it was estimated 120 million people; approximately 2% of the global population presented with some type of disabling hearing loss (Nelson et al., 2005; Suzuki, Kobayashi, & Koga, 2012).This figure doubled to 240 million cases in 2003 (Suzuki et al., 2012). Nelson et al. (2005) attributed disabling hearing loss to exposure to noise on the job, although there is limited data on the precise prevalence. In 2005, Nelson et al. (2005) estimated the prevalence of ONIHL to be between 7% and 21% globally. Recently, Feder et al. (2017) estimated the rate of ONIHL to be between 16% and 24% world-wide. This indicates a rapid increase in ONIHL globally; affecting developing countries more than developed ones (Chadambuka et al., 2013; Miah et al., 2014).

In the United States of America, Concha-Barrientos et al. (2004) estimate that approximately 30 million workers are exposed to excessive noise in the workplace, increasing the risk of developing ONIHL. Of these workers, approximately 9 million are exposed to time-weighted average (TWA) sound levels of 85 dBA and above (Nelson et al., 2005; Suter, 2000), and about 10 million have ONIHL greater than 25 dB (Nelson et al., 2005). Tak and Calvert (2008) conducted a study between 1997 and 2003, where the findings indicated that ONIHL was responsible for 24% of hearing loss cases in workers aged between 18 and 65 years. Masterson et al. (2013) investigated 1,122,722 audiograms from 2000 to 2008 to determine the prevalence of ONIHL in industries known to have a high prevalence of excessive noise. Overall findings indicated that 18% of the workforce had ONIHL with mining and manufacturing presenting the highest prevalence and risk of developing ONIHL.

Interestingly, in 2010, Hoffman, Dobie, Ko, Themann, and Murphy (2010) reported a lower prevalence and severity of ONIHL in America compared to 40 years ago. These authors

surmised this decline in ONIHL burden may be attributed to increased enforcement of hearing protection strategies and a reduction in manufacturing. It is therefore unclear if the findings by Masterson et al. (2013) are reflective of findings by Hoffman et al. (2010).

In Europe, an estimated 30 to 50 million workers are exposed to hazardous noise levels and are at risk of developing ONIHL (Prasher et al., 2002). According to the European Agency for Safety and Health at Work (2005), between 2000 and 2001 approximately 29% to 35% of the workforce was exposed to high levels of noise, particularly in sectors such as agriculture, forestry, fishing; mining; utilities; manufacturing and construction. According to Safe Work Australia (2010) between 2002 and 2007, ONIHL accounted for to 10% of the total hearing loss in the adult population. This was determined by the number of compensation claims (16,500) for ONIHL received and processed in this period. Of these claims, 65% were from manufacturing, construction, and transportation sectors (Safe Work Australia, 2010). It was also noted that per million employees, the rate of compensation increased over a nine-year period – from 491 in 2001 to 523 claims in 2009 (Safe Work Australia, 2012).

In South Africa, data on the prevalence of ONIHL is not readily available, thus, data discussed in this study specifically relates to the mining industry. The researcher is cognisant that actual figures on the prevalence of ONIHL in South Africa may be significantly higher than reported in this study. Recent data on the prevalence of ONIHL is not currently available. Statistical information on the prevalence of noise exposure was obtained from Rand Mutual Assurance, a non-profit organisation responsible for administrating mineworkers' compensation.

In 2007, Hermanus (2007, p. 534) reported that, based on data available then, nearly half the mine's workforce was exposed to "deafening noise, and of these workers more than 90% work

in zones in which noise exceeds the 85 dBA time weighted average, with 11% working in zones in which the noise levels are even higher".

In 2011, Edwards et al. (2011) reported that approximately 73.2% of the workforce was exposed to noise levels above the legislated occupational exposure level of 85 dBA. In 2012, the Chamber of Mines, as cited by Strauss, Swanepoel, Becker, Eloff, and Hall (2014) reported that 3.1 out of every 1000 workers have ONIHL. Reporting on the prevalence of ONIHL in the South African mining sector, Strauss et al. (2014) further stated that several factors such as non-occupational noise exposure and vibration, as well as biological factors increased the prevalence of ONIHL. These biological factors include smoking, age, gender, genetics, ototoxic drugs and illnesses such as tuberculosis. These factors contribute to individual susceptibility to ONIHL.

2.3 Risk Factors Associated with Exposure to Excessive Noise

ONIHL is a complex disease (Le et al., 2017). Regardless of the amount of noise exposure an individual is exposed to, some people are more prone to developing hearing loss when compared to others subjected to the same level and amount of noise (Daniel, 2007; Sliwinska-Kowalska et al., 2005). However, it is still not known why this is the case (Sliwinski-Kowalska & Davis, 2012). Individual susceptibility or risk factors associated with ONIHL can either be non-modifiable – outside one's control, or modifiable – within one's control (Daniel, 2007).

Non-modifiable factors include age (Daniel, 2007; Dobie, 2001; Kerketta, Gartia, & Bagh, 2012; Pyykkö, Toppila, Zou, & Kentala, 2007; Rosenhall, 2003; Toppila, Pyykkö, & Starck, 2001), race (Cunningham & Norris, 1982; Daniel, 2007; De Koker, Franz, Clark, & Mackay, 2003;

Pyykkö et al., 2007), and gender (Daniel, 2007; Ecob et al., 2008; Guimaraes, Zhu, Cannon, Kim, & Frisina, 2004; Kilicdag et al., 2004; Pratt et al., 2009).

Modifiable factors include smoking (Ecob et al., 2008; Fabry et al., 2010; Ferrite & Santana, 2005; Sharabi, Reshef-Haran, Burstein, & Eldad, 2002), ototoxic agents (Kirchner et al., 2012; Sliwinska-Kowalska et al., 2006), and ototoxic drugs (used to treat diseases like HIV/AIDS. TB and cancer), (Arslan, Orzan, & Santarelli, 1999; Assuiti, Lanzoni, dos Santos, Erdmann, & Meirelles, 2013; Campo, Morata, & Hong, 2013; Khoza-Shangase, 2010, 2013; Khoza-Shangase, Mupawose, & Mlangeni, 2009; Li & Steyger, 2009; Schellack & Naude, 2012). The afore-presented risk factors present a challenge to individuals who are exposed to occupational noise; as they undoubtedly lead to negative effects on ear care, health and safety for individuals subjected to such excessive noise.

2.4 **Effects of Exposure to Excessive Noise**

Universally, hearing loss acquired in adulthood is ranked the fifteenth most serious health issue. (Chia et al., 2007; Fabry et al., 2010; Nelson et al., 2005). Although hearing loss is not life threatening (Hong et al., 2013; Le et al., 2017), unmanaged hearing loss may have a profound impact on the quality of life and wellbeing of the affected individual. These negative effects can be experienced through reduced social activity, feelings of exclusion from social participation, symptoms of depression, stigma associated with hearing loss, and loss of self-esteem (Chadambuka et al., 2013; Kurmis & Apps, 2007). These effects can be classified into two categories – auditory and non-auditory effects (Shendell, Barnett, & Boese, 2004).

Auditory effects are caused by the direct impact of exposure. These may include tinnitus (Delecrode, de Freitas, Frizzo, & Cardoso, 2012; Steinmetz, Zeigelboim, Lacerda, Morata, & Marques, 2009); temporary threshold shifts, as well as a permanent threshold shift resulting in hearing loss (Arlinger, 2003 ; Hind et al., 2011; Pienkowski, 2017; Ryan, Kujawa, Hammill, Le Prell, & Kil, 2016). Non-auditory effects result from indirect impact of exposure to excessive noise. These may manifest through annoyance, masking of warning signals, communication difficulties among workers, increased blood pressure of exposed workers, and may affect job performance of some workers (Ahmed, 2012; Basner et al., 2014; Park et al., 2017).

The presence of a hearing loss in the workplace has adverse implications for occupational safety as well as work-related injuries (Amjad-Sardrudi et al., 2012; Deshaies et al., 2015). Potentially, prolonged exposure to noise in the workplace may lead to increased fatigue and decreased concentration, which ultimately increases the probability of human error (Amjad-Sardrudi et al., 2012). There is limited information available on hearing loss and its contribution to work injuries. This tends to underestimate the impact of noise exposure and its potential effect on occupational injuries (Amjad-Sardrudi et al., 2012; Girard et al., 2009; Monazzam, Golmohammadi, Nourollahi, & Momenbellah-Fard, 2011). Nonetheless, in the few studies conducted by Amjad-Sardrudi et al. (2012); Coderio, Clementa, Diniz, and Dias (2005); (Dias & Cordeiro, 2008), findings indicate that dangerous noise exposure levels in the workplace are a potential risk factor for occupational injuries. This is particularly true for workers exposed to noise above 85dB(A), as is the case in the South African mining industry.

ONIHL can significantly compromise communication among workers in the workplace, thereby presenting challenges for safety and productivity (Amjad-Sardrudi et al., 2012; Kanji et al., 2017). Even mild hearing loss in the workplace can be catastrophic and interfere with

participation (Kramer, Kapteyn, & Houtgast, 2006; Monzani, Galeazzi, Genovese, Marrara, & Martini, 2008). Compromised communication can adversely affect performance and productivity in a number of ways. Firstly, it can potentially reduce the worker's ability to perform or complete tasks dependent on auditory signals or verbal communication (Thorne, 2006) Secondly, workers may be viewed as incompetent or inactive due to the presence of a hearing loss and compromised communication. (Momm & Geiecker, n.d.). Thirdly, compromised communication among workers can impede teamwork and group productivity (Momm & Geiecker, n.d.). Lastly, it can lead to safety concerns, as workers may not be able to hear warning signals such as sirens since high frequency sounds are the most affected. Thereby increasing risks of accidents in the workplace (Kirchner et al., 2012).

Reportedly, workers with a hearing loss seemingly report a high degree of psychosocial distress perceived as lack of energy and social isolation (Grimby & Ringdahl, 2000; Kramer, 2008; Monzani et al., 2008). Kramer et al. (2006) reported that individuals with a hearing loss were more sensitive to background noise thereby increasing the incidence of absenteeism from work due to fatigue, mental distress and strain. The incidence of absenteeism was reportedly five times greater in individuals with hearing loss compared to peers without a hearing loss (Kramer et al., 2006). Findings from this study highlight the need to pay focused and prioritised attention to workers with hearing loss in the workplace. This is because these workers may be susceptible to mental distress, which can also negatively affect health as well as occupational performance among individuals exposed to excessive noise in the workplace.

In this study, a search for studies on the effects of ONIHL on mental health of workers exposed to excessive noise yielded only one strategy document, which was not an empirical study, on occupational health and employee well-being (Sasol, 2014). This is an important consideration

in the South African context, since the mining industry is one of the largest employers in the country and the majority of its workforce is exposed to excessive noise in the workplace. Possibly, some workers may be experiencing noise annoyance due to excessive noise in the workplace. (Basner et al., 2014; Stansfeld & Matheson, 2003).

Noise annoyance is "a feeling of resentment, displeasure, discomfort, dissatisfaction, or offense when noise interferes with someone's thoughts, feelings, or actual activities". (Passchier-Vermeer & Passchier, 2000, p. 26). Noise annoyance is said to interfere with activities of daily living, and is often accompanied by negative feelings such as anger, exhaustion and stress-related symptoms (Ohrstrom, Skanberg, Svensson, & Gidlof-Gunnarsson, 2006). These negative emotions thereby impact on the wellbeing and health of the affected individual (Basner et al., 2014; Fritschi, Brown, Kim, Schwela, & Kephalopoulos, 2011). Studies have found individuals exposed to excessive noise, depending on the severity of the exposure, display moderate levels of annoyance when exposed to noise levels of 70 – 96 dBs in the workplace (Ahmed, 2012). Therefore, catastrophic levels of annoyance are a concern as they are associated with depressive symptoms and even thoughts of suicide (Yoon, Won, Lee, Jung, & Roh, 2014). Therefore, there is a need to monitor noise annoyance levels of individuals exposed to excessive noise in the workplace, as noise seems to negatively affect the well-being of these individuals. In the South African mining sector, although there are no accurate figures, Hermanus (2007) and Edwards et al. (2011) conceded that a large number of workers are exposed to noise levels exceeding the stipulated legislation.

Therefore, it can be argued that a large portion of the workforce is potentially present with catastrophic levels of noise annoyance. Currently, there are no studies conducted on the relationship between noise annoyance and mental health issues in South African work sectors

where employees are exposed to excessive noise. Failure to address these non-auditory factors particularly in developing countries negatively impacts workers thereby precipitating occupational injuries and ill health within the workforce. This leads to further social and economic implications for individuals, their families and their communities. Ultimately, these negative factors give rise to damaging economic impacts upon the entire society (Hermanus, 2007).

2.5 Socio Economic Impact of Exposure to Excessive Noise

Excessive noise exposure is a significant public health problem in the workplace (Hong et al., 2013; Ntlhakana et al., 2015), resulting in occupational injuries, ill-health, absenteeism, as well as social and economic implications for individuals, their families, community and the State at large (Amjad-Sardrudi et al., 2012; Coderio et al., 2005; Dias & Cordeiro, 2008; Hermanus, 2007; Kramer et al., 2006).

Economically, there are direct and indirect costs to the society and State (Hermanus, 2007). Direct costs involve occupational injuries including compensation costs, costs associated with damage in the workplace, and the cost of interruption of production. Indirect costs include the expense of livelihoods lost and income for dependents (Hermanus, 2007).

According to Hong et al. (2013) the impact of ONIHL on one's health and quality of life cannot be quantified in tangible measures or standards. However, compensation costs for ONIHL are consistently increasing. Globally, 250 million people suffer with noise induced hearing loss (NIHL) (Seidman & Standring, 2010). Of this population, 16% have ONIHL resulting in disabling hearing loss, presenting serious implications for economic production (Nelson et al., 2005; Seidman & Standring, 2010). Furthermore, the approximated total cost for occupational accidents

and disease represents between 1 and 3% of the Gross Domestic Product (GDP) various countries (Rikhardsson, 2004)

According to Basner et al. (2014), in America, approximately 242 million dollars are spent on compensation for ONIHL annually. In report on noise presented to the United States Government Accountability Office in 2011, ONIHL was the most prevalent occupational health disability in the Department of Defence (Yankaskas, 2013). According to this report, in the fiscal year 2010, the Veterans Affairs Department compensated over 1.2 billion dollars to more than 1.4 million veterans due to hearing impairment. In Australia, ONIHL was reported at 5755 cases in 1998/9; 5280 in 1999/2000; 5185 in 2000/1 and ultimately decreased to 4510 cases in 2001/2. This translated to 19% of all disease related-claims in the workplace (Australian Safety and Compensation Council, 2006). The steady decline in ONIHL in Australia is worth noting. According to the report, this decline in claims from 5 755 to 4510 cases is attributed to the reduction of claims made in the manufacturing industry (Australian Safety and Compensation Council, 2006). However, the precise reasons for the reduction of claims are not provided. The report further states that mining, particularly coal mining, presented the highest incidence of 762 out of 100 000 of ONIHL claims (Australian Safety and Compensation Council, 2006).

These findings strongly indicate that the mining sector in general represents the heaviest burden on the economy. This was corroborated by Matetic (2005) who stated that, according to the Center for Disease Control, 49% of male miners are likely to acquire a hearing loss by age 50. This is compared to 9% in the general public. Furthermore, this figure rises to 70% by age 60.

Statistics on the burden of ONIHL in developing countries is not readily available (Nelson et al., 2005). However, Chadambuka et al. (2013, p. 889) argue 80% of individuals affected by ONIHL reside in low and middle income countries where ONIHL presents a “much heavier burden

in developing countries then in developed regions of the worlds". India for example, under the Employees State Insurance Act (1948) and the Workman's Compensation Act (1923); ONIHL has been compensable since 1948. However, there is little awareness or knowledge regarding this fact since the initial payment was only made in 1996. (Nandi & Dhatrak, 2008). According to Nandi and Dhatrak (2008), approximately 250 workers are receiving compensation for ONIHL but the processing costs towards compensation are not disclosed.

In South Africa, RMA insures approximately 80% of mining industry workers. Roughly, 12% of the occupational injury and disease claims processed annually by the RMA are due to ONIHL. In 2004, this cost was estimated at R15 000 per person (Begley, 2004), resulting to approximately R75 million paid out in compensation claims in the same year (Hermanus, 2007). Although the specific amount are not given, according to Edwards and Kritzinger (2012), RMA has paid hundreds of millions of rands towards NIHL from 1998-2007 to the mining sector. These high compensation claims illustrate the costly effects and consequences of poorly managed ONIHL. The effects of ONIHL, particularly in a developing country such as South Africa, should not be underestimated as they extend beyond compensation pay-outs. ONIHL potentially presents a limitation on the kind of employment suitable for a person with a hearing loss (Thorne, 2006). This may lead to heavy economic burdens, predominantly for developing countries.

2.6 **South African mining industry in context**

South Africa's mining history has had a pronounced effect on the economy, politics, health and safety, and the general wellbeing of mineworkers and the mining industry at large. The roots of these challenges stem from the history of colonialism and the introduction of apartheid in the mining industry. Although apartheid was formally legalised in 1948, its roots were established

with the arrival of the Europeans in 1952 (Benson, 2016; CJPME Foundation, 2014), and its effects seem to continue to this day.

Historically, the workforce in the mining industry comprised a majority of Black males, who were previously disadvantage in terms of education and skilled labour (Kane-Berman, 2017; Smit & Mji, 2012; Worldwide Recruitment Solutions, 2014). These historical disadvantages and injustices have presented a perpetually devastating outcome not only for the mineworkers but also for their families, the mining industry and the state at large.

In South Africa, according to Menon (2017) unemployment has been its highest since 2003, with a highest prevalence (33.1%) among people who have less than a matric education, making this category 5.4% higher than the national average. Historically, most mineworkers, particularly Black South Africans, had low levels of education and literacy due to past social and economic injustices imposed on Black people during the apartheid era. For instance, according to Smit and Mji (2012), most workers in the mining industry are illiterate, consequently, they are restricted to performing manual labour jobs since such work does not require any form of education. In 1996, approximately 80% of all mineworkers (unskilled) had an education level lower than Grade 7 and were illiterate and innumerate. A decade later, in 2006, 67% of mine workers still had not obtained a grade 7 education. Furthermore, a quarter of this 67% had no formal education at all (Smit & Mji, 2012).

Arguably, improvement may have occurred in recent years, due to the surge of millennials entering the mining industry. Nevertheless, unemployment is still high among graduates in South Africa (Graham & Mlatsheni, 2015; Oluwajodu, Blaauw, Greyling, & Kleynhans, 2015). Therefore, low levels of education in the presence of hearing loss and disability, has adverse consequences for most mineworkers. This subsequently adds further economic encumbrance to a

country already laden with a quadruple burden of disease (Yerramilli, 2015), which further contributes to the economic burden of the entire country.

Negative effects of low levels of education and unskilled labour were also reflected in the remuneration or salaries paid to Black workers in the mining sector. According to Kane-Berman (2017) in the 1970s, the average salary for a White worker was 16 times more than that of a Black worker. Salary differences were based on different skills levels, and the results of the industrial colour bar and Bantu Education system which ensured Black people remained unskilled (Kane-Berman, 2017). Furthermore, the difference in salaries reflected the government's unilateral negotiation of salaries as unions for Black people were banned during the apartheid regime.

Post democratic dispensation, in 2003, the average entry level salary for a mineworker in a gold mine was approximately R5000, rising to R8000 with the inclusion of housing and food allowance. Overtime and bonuses improved the salaries to R11 000 a month (Reuters, 2013). However, the reality is that South Africa as a developing country is marred with high levels of unemployment, poverty and an unequal society (Kihn, nd). In 2012, it was reported that "the salaries of chief executives in the mining sector have quadrupled over the past few years despite the global economic crisis and are 150 times higher than the pay of an average mineworker" (Letsoalo & Molele, 2012, p. 1). Kihn (nd) argues that when comparing South African mine workers' salary to other developing countries, like China or India, South Africans are relatively well-paid. However, when compared to developed countries, like Canada, South Africans are paid nearly six times less than the Canadians are.

To put this into perspective, South Africa has dominated the mining industry for about 120 years, reaching its peak in 1970. Although in 2004 there was a slight decline in production, South

Africa nevertheless remains the biggest producer of gold globally, maintaining its growth economically (South African Resources, 2012). This is, however, not consistent with the income levels of those who work in the mines.

As a consequence of this inconsistency regarding salaries and living conditions – which will be discussed below – workers in the mining industry embarked on a massive strike in 2012 which resulted in what is now termed the Marikana Massacre. The Marikana Massacre took place on 16 August 2012, when 34 people were killed and 78 wounded (Hill & Maroun, 2015). The strike was initiated by approximately 3000 rock drill operators who demanded an increase from R4 000 to R12 500 per month (Coleman, 2012; Muswaka, 2014).

Post analysis of the events leading to the massacre revealed five major areas of concern for the mines. Firstly, mineworkers were aggrieved by the greed of the employers and the mining industry (Twala, nd). Reportedly, post 1994, the platinum industry "has generated 'fabulous wealth' for companies and executives, but social squalor, tensions and poverty for workers and communities" (Coleman, 2012, p. 4). Secondly, the mining industry had fragmented its workforce of 180,000 letting 82, 000 employees to be employed through labour brokers. Additionally, workers were divided on ethnic, racial and regional lines, which resulted in frustrations among workers who witnessed employers continue to become rich at their expense while they "sweat underground, face death on a daily basis and sink deeper into poverty" (Twala, nd, p. 62). Thirdly, the government's ineffectiveness in implementing the Mining Charter, which among other things, required companies to provide housing for all mineworkers. Fourthly, the ineffectiveness of the labour movements in handling the workers' grievances adequately. Lastly, criticisms against the government of the ruling party and the State machinery in their perceived failure to address the workers' problems" (Twala, nd).

To further contextualise the current study, it is important to understand the pre-1994 health and safety standards in the South African mining sector. Pre-1994, the health and safety of mineworkers was largely neglected by both the mine owners and policy makers (National Institute for Occupational Safety and Health [NIOSH], 1996; Roberts, 2009). Consequently, mineworkers, particularly Black miners, were subjected to unhygienic and unsafe working conditions.

For example, Katz (1994) wrote a book entitled "The White Death. Silicosis on the Witwatersrand Gold Mines 1886 – 1910" which provided a historical background of the extent of silicosis – a lung-disease due to inhaling silica dust in gold mines – among White miners from England. According to this author, "between 1892 and 1910 almost an entire generation of professional miners from abroad died from an accelerated form of silicosis" (Katz, 1994, p. 213).

Reportedly, the issue of silicosis among White miners drew attention in the early 20th century, between 1902 and 1925 due to its prevalence of approximately 25% among underground white miners. Black miners on the other hand; "would have to wait until 1993 for the last racist legislation on the statute books, for all clauses instituting differentiating provisions on the basis of populations groups, to be removed so that all the de jure provisions of the ODMWA (Occupational Diseases in Mines and Works Act 78 of 1973) applied equally to them" (Roberts, 2009, p. 18). True to the sentiments by Roberts (2009, p. 17):

> "The fate of black South African migrant miners has [come], close to a hundred years later, [is] yet to be fully recorded. Decades upon decades have passed without the graves of South African miners, who have returned to their homes in the labour-sending areas of the country, being counted in any epidemiological reports. A grave is too late for any epidemiological inquiry".

It was only in 2012, that previous and current gold mineworkers filed a class action suit against the South African mining industry (Reuters, 2018). Although the outcome of the class action ruled in favour of Black South African and Lesotho miners, who are the majority claimants, for some miners, this outcome came a bit too late as they died before the class action even began.

Coupled with silicosis, workers were also exposed to excessive occupational noise in the mines. Similar to silicosis, the impact of excessive noise on Black miners was ignored. A literature search into ONIHL in the mining sector in South Africa prior to 1994 only revealed one study which was conducted on White mineworkers by Hessel and Sluis-Cremer (1987), to the exclusion of Black workers who formed the majority of the mines' workforce. It was only in 1994 that Kahan and Ross (1994) conducted a study on Black mineworkers; the same year that apartheid was abolished. The findings of this study conducted on Black workers revealed that these workers had not been informed of the dangers of exposure to excessive noise in the absence of hearing protection. These results confirmed a statement by Simons (1960) who asserted, pre-1994, Black workers were not given instruction on occupational health and safety issues as they were seen as incapable of learning. Interestingly, in the ruling of the silicosis class action, the mines were penalised by the High Court for failing to provide mineworkers with adequate protection during and even after apartheid rule ended in 1994 (Reuters, 2018).

Lastly, pre-1994, Black miners were subjected to a compound system as a means of accommodation (Kane-Berman, 2017; Simons, 1960). The compound system was established to prevent Black workers being absent from work, discourage drunkenness and minimise risk of theft (Kane-Berman, 2017). Living conditions in the compounds were unhygienic and unhealthy (Wilson & Churches, 1972); consequently, diseases such as TB, HIV/AIDS, silicosis became rife in the mining sector.

Post the democratic dispensation; South Africa was among the countries with the highest incidence of HIV/AIDS, as well as TB with the highest prevalence of these diseases in the mining industry (Stuckler et al., 2011; Stuckler et al., 2013). In 2013, with between 3000 and 7000 cases per 100,000 people per year, South African gold mineworkers were listed among those with the highest incidences of TB globally. According to a report by Deloitte (2005), approximately one third of mineworkers acquired HIV within 18 months of being employed at the mines. AngloGold Ashanti West Wits country report estimated approximately 85% of their employees were diagnosed with TB as well as HIV (AngloGold Ashanti, 2012). The presence of HIV infection increases the probability of acquiring TB, which is aggravated by poor working and living conditions (Bhunu, Mushayabasa, & Smith, 2012; Stuckler et al., 2013).

According to World Bank as cited by Cullinan (2018, p. 1) "In South Africa alone, TB rates within the mining workforce are estimated at 2 500 to 3 000 cases per 100 000 individuals. This incidence is 10 times the WHO threshold for a health emergency, and is also nearly three times the incidence rate in the general population." These assertions were made with regard to the R1,4 billion settlement for miners who had contracted silicosis and TB after 12 March 1965. One of the claimants from this class action stated:

> "We weren't given masks and were sent in after they [the mining companies] would blast and blast, not even waiting 15 minutes. The doctors say I won't get better, and all I want is to have my voice heard. I don't want future miners to suffer like I do," (Cullinan, 2018).

With regard to the compensation awarded to the miners, some supporters expressed their views:

> "As TAC and Sonke Gender Justice, we recognise that no compensation can make up for the loss of loved ones, or the loss of one's health or ability to work. We also note that the

amounts that former mineworkers or their surviving family members will be receiving are in no way sufficient compensation. However, we also recognise that insufficient as the settlement may be, it is more than people would have received under the existing compensation framework, and as such we welcome it." (Cullinan, 2018).

The presence of noise in any country, regardless of whether it is developed or not, has devastating effects. However, the impact becomes even more burdensome if a country is faced with challenges such as the quadruple burden of disease as is the case in South Africa (Yerramilli, 2015). Therefore, ONIHL, in the presence of low education and literacy levels, low salaries, poor occupational health and safety awareness and diseases such as HIV/AIDS have a profound effect on South Africa. These effects are not only limited to the individual who is affected, but extends to their families as in most cases, these workers are the sole providers or breadwinners for their families. Furthermore, this impact has had an effect on the company/organisation as they incur costs through compensation for occupational health and safety claims. Lastly, due to the effect that ONIHL is a disability, most workers diagnosed with a hearing loss cannot continue with their occupations. Consequently, they must rely on State resources for their up keep.

It is for this reason that ONIHL is considered one of the greatest threats to the country's economic and public health systems. The South African context paints a true picture of the effects of ONIHL in a developing country. It is against this background this current study was conducted. This study aimed to explore the management of ONIHL in the mining industry to ascertain realistic and evidence-based approaches of managing this epidemic within the South African mining industry, which remains a developing country.

2.7 Management of Excessive Exposure to Noise in the Workplace

Exposure to hazardous occupational noise is preventable through effective HCPs. These are multi-component interventions aimed at managing noise-induced hearing loss, thereby protecting employees exposed to excessive hazardous noise in the workplace (Amedofu, 2007; Hong et al., 2013; Seixas et al., 2011). However, HCPs are only successful if the following pillars are implemented: periodic noise exposure monitoring, engineering controls; administrative controls, personal hearing protection, audiometric evaluations and employee/management education and training, and record keeping (Amedofu, 2007; Hong et al., 2013). There is evidence to suggest HCPs are effective in managing and protecting workers from acquiring ONIHL, especially in developed countries (Davies, Marion, & Teschke, 2008; Dobie, 2008; Lie et al., 2015; Nelson et al., 2005; Rabinowitz, 2012).

In South Africa, published evidence indicates HCPs are not yet successful. Studies conducted to evaluate the effectiveness and efficacy of management of ONIHL through HCPs within the South African mining industry yielded unfavourable findings (Edwards et al., 2011; Edwards et al., 2015; Edwards & Kritzinger, 2012). These studies highlight a significant need for focused and deliberate effort towards the management of hazardous occupational noise in the mining industry.

Evidence suggests the failure of HCPs in the South African mining industry is a result of a several issues:

1. targeting of individual pillars at the expense of neglecting certain other pillars;
2. lack of prioritising the hierarchy of control in the management of noise,
3. the absence of audiologists in the implementation and evaluation of HPCs.

A review of studies on HCPs in the mining industry indicates a heavy focus and reliance on the use of personal hearing protection devices as a method of prevention. For instance, a number of studies conducted in South Africa have focused on the use of HPDs (Hansia & Dickinson, 2010; Kanji et al., 2018; Kock, 2013; Ntlhakana et al., 2015; Ross, 1992; Steenkamp, 2003; Steenkamp & 2008). Most of these studies have downplayed the importance of engineering controls, which according to the hierarchy of controls is the first defense against noise exposure in the workplace. According to the Department of Minerals and Energy guidelines (DME, 2003), the use of personal protection devices should be the last resort if/when engineering and administrative controls fail.

Furthermore, more evidence suggests a very limited number of studies conducted on *"buying quiet"*, (Burger, von Wielligh, de Wet, Otterman, & Steyn, 2004; Gumede, Blomerus, Coutts, & De Beer, 2014), administrative controls (Steenkamp, nd); education and training (Edwards et al., 2011), as well as audiometry testing (De Koker et al., 2003). A review of literature on HCP pillars indicated that periodic noise exposure monitoring, audiometric noise exposure measurements and HCP record keeping are often neglected pillars in comprehensive HCPs. Omitting periodic noise exposure monitoring has implications for the entire HCP as this pillar serves to identify individuals exposed to excessive noise in the workplace (Workplace Safety and Health Council, 2014). There is a possibility information on periodic noise exposure may be company-specific and therefore not made available in the public domain or to researchers who may be investigating HCPs in the mining sector. Hence, the dearth of literature on this pillar. Nevertheless, according to the Workplace Safety and Health Council (2014), noise monitoring should be conducted every time alterations are introduced and applied on the machines. Otherwise, if there are no changes introduced in the workplace, such monitoring should be performed every three years.

A paucity of evidence exists record keeping in the mining industry as well. To maintain accountability, effective record keeping is crucial and promotes commitment and consistency (Byrne, 2005). Considering ONIHL develops gradually and overtime, the importance of keeping accurate records of each employee becomes critical and cannot be over emphasised. Records can be used to determine an employee's exposure to noise, thereby allowing for effective and accurate programme evaluation, which is important for programme sustainability. Accurate record keeping allows for easy identification of programme changes and identifying challenges (Byrne, 2005). Proper record keeping also allows for accurate and appropriate individual conservation programme implementation where employees' compounding factors such as concomitant exposure to other toxins – such as co-occurrence of TB and HIV with ototoxicity – can be taken into careful consideration in employee HCP plans. Furthermore, proper record keeping allows for accurate comparative analysis of employee thresholds for compensation purposes; should this eventuality come. Proper record keeping also facilitates accurate research to be conducted to allow for relevant evidence-based information can be accessed by the mining industry to enhance their HCPs (Byrne, 2005).

The review of literature into the role of audiologists in the management of ONIHL in South Africa revealed the absence of audiologists. While there are a number of studies conducted by audiologists into the management of ONIHL in the mining sector, no single study has focused on the role of audiologists in the implementation and evaluation of HCPs implemented at various mines in South Africa. This is quite concerning as the scope of practice of audiologists as detailed in the Health Professionals Council in South Africa (HPCSA) is silent on the role of audiologists in occupational audiology and management of ONIHL in South Africa. Nevertheless, the search

for the role of audiologists in the management of ONIHL in the South African mining sector revealed two guidelines.

The first guideline states audiologists are 'competent persons' in conducting baseline-hearing levels in the medical surveillance of people exposed to occupational noise in the workplace (de W Oosthuizen, 2006). However, this guideline limits the role of audiologists in the management of ONIHL in the mining sector to audiometric surveillance. This is a role they share with audiometrists, occupational hygienists and occupational medical practitioners as long as they are registered with the HPCSA and/or the South African Society of Occupational Health Nursing Practitioners (SASOHN) (de W Oosthuizen, 2006).

The second guideline, retrieved from the HPCSA website, was a draft guideline on industrial/occupational audiology, authored by Dr de Koker who is also an audiologist (De Koker, n.d.). This guideline is silent on the proactive role of audiologists in preventing hearing loss and focuses on a reactive role of compensating workers who incur hearing loss in the workplace. Yet, the primary role of an occupational audiologist is to prevent hearing loss as supported by the American Academy of Audiology, which states the role of audiologists as principal advocates for and supervisors of programs to manage the hearing health of people exposed to hazardous noise' (American Academy of Audiology, 2003). Therefore, audiologists are responsible for "designing, implementing and coordinating occupational and community hearing loss prevention programmes (American Academy of Audiology, 2003).

This role necessitates the identification and amelioration of noise-hazardous conditions, identification of hearing loss, recommendation and counselling for use of hearing protection, employee education, and the training and supervision of non-audiologists performing monitoring audiometry in the occupational setting (American Academy of Audiology, 1997). Although the

role of audiologists is clearly spelled out, evidence indicates both internationally and locally, there are few audiologists who serve as consultants in the mining industry, and even fewer involved in noise measurements, training of occupational hearing conservationists, or in HCP audits, implementation, and evaluation of programmes (American Speech-Language-Hearing Association, 1997).

2.8 **Chapter summary**

This chapter provided an overview of ONIHL and its impact, particularly in developing countries like South Africa. This chapter also highlighted challenges faced by the South African mining industry in combating ONIHL; with a history of mining in South Africa provided as context. These challenges included heavy reliance upon hearing protection devices as the most commonly adopted strategy in the management of ONIHL, as well as the exclusion of audiologists in the prevention and management of ONIHL in the mining sector.

CHAPTER 3. RESEARCH INTO OCCUPATIONAL NOISE INDUCED HEARING LOSS IN SOUTH AFRICAN LARGE-SCALE MINES: ACCESS DENIED?



Health at work and healthy work environments are among the most valuable assets of individuals, communities, and countries. *(Global Strategy on Occupational Health for All 1994)*

Research into Occupational Noise Induced Hearing Loss in South African Large-Scale Mines: Access Denied

(Reprinted with permission, see appendix G)

3.1 Abstract

The South African mining industry is frequently criticised for its poor health and safety record and high numbers of fatalities, prompting research on challenges faced by this industry. This study aimed to investigate the feasibility of conducting audiological research into occupational noise-induced hearing loss (ONIHL) within the South African mining sector. Specific objectives included determining ease of identifying focal persons in charge of hearing conservation programmes (HCP); establishing response time and rate of identified focal person for interviews; and exploring focal person's willingness to share information regarding HCP.

Methods: A qualitative research strategy was undertaken, comprising online research, interviews and purposive sampling to recruit participants**.** Data were collected through checklists, logbooks and interviews. Data was analysed though deductive thematic analysis.

Results: Gaining access into the mining sector is negatively impacted by the following three factors: contact details of focal persons are not always listed on the websites. Secondly, a long passage of time from initial contact to responses from focal persons. Lastly, unwillingness to share information regarding the management of ONIHL and progress made in HCP at various mines.

Conclusions: Findings reflect possible barriers to effective and successful implementation of application of best practice in HCPs. Challenges with accessing mines for research purposes by external and independent researchers arguably impacts on the available evidence produced by mines, due to a possible unavoidable conflict of interest. Success of HCPs depend on objective

evidence regardless of whether it is a positive or negative reflection of the mining industry. It is only when this evidence is critically engaged with, that real and effective solutions can be deliberated and implemented. Clear, transparent, and open lines of communication between various stakeholders are key to achieving this.

3.2 Introduction

The mining industry in South Africa remains one of the driving forces of the country's economy. Currently, mining in South Africa is reported as a significant contributor to the economy in that, firstly, it contributes an average of 20% to South Africa's GDP. Secondly, it boasts a total annual income of nearly 550 billion rand. Thirdly, it is one of the country's biggest employers with more than a million personnel in mining-related employment, with the majority being Black males. Lastly, it has been regarded as the largest contributor by value to black economic empowerment in the economy (Worldwide Recruitment Solutions, 2014). However, the South African mining industry has not paid adequate attention to occupational health and safety, hence the high numbers of fatalities (Cullinan, 2018; Nkosi et al., 2015; Teke, 2017). Ear and hearing health in the form of noise induced hearing loss is one of the health and safety conditions requiring the attention of the South African mining industry.

Occupational noise induced hearing loss (ONIHL) is a prevalent condition in the mining industry and has been classified as a number one work-related disability, the second most common form of acquired hearing loss after presbycutic (age-related) hearing loss with severe consequences for those exposed to high levels of noise (Ritzel & McCrary-Quarles, 2008). This type of hearing loss is not a phenomenon that is unique to South Africa. In the United States of America, it is estimated that approximately 30 million workers are exposed to excessive noise in the workplace, and are reported to be at risk of developing ONIHL (Concha-Barrientos et al., 2004). In Europe, an estimated figure of 30 to 50 million workers are exposed to hazardous noise levels and are also at risk of developing ONIHL (Prasher et al., 2002). Approximately a million employees in Australia are potentially exposed to high levels of hazardous noise at work. In 2002, 4510 cases of compensation claims were reported and, and as a result, the number of hearing loss

compensation claims was estimated at 4510 individuals in 2002 - this represented 19% of all disease-related claims processed in the same year (Yamashita et al., 2005) . Locally, data from some South African mines indicates that almost half of the mines' workforce is exposed to hazardous noise and that 90% of these workers are exposed to noise levels exceeding 85 decibel A weighted (dBA) in intensity over and above an 8 hour working shift for a 40 hour per week time weighted average (TWA). Furthermore, 11% of the workers are exposed to noise levels that far exceed this 85 dBA limit (Hermanus, 2007).

Although hearing loss is not life threatening, unmanaged hearing loss may have a profound impact on the quality of life of the affected individual. Impoverished quality of life may manifest through reduced social activity and feelings of exclusion from social participation, which may ultimately give rise to increased prevalence of symptoms of depression, stigma associated with hearing loss, and loss of self-esteem (Chadambuka et al., 2013). Occupationally, noise induced hearing loss has a potential of significantly reducing the worker's ability to perform or complete tasks that are dependent on auditory signals or verbal communication (Thorne, 2006). Furthermore, due to hearing loss sustained at work, which subsequently results in a communication handicap, workers may be regarded as incompetent or inactive, which ultimately, will impact on team work and group productivity (Momm & Geiecker, n.d.). Moreover, hearing loss can negatively affect communication among workers, which can lead to safety concerns as workers may not be able to hear warning signals such as sirens since high frequency sounds are the most affected. Compromised ability to communicate may lead to increased risks of accidents (D. B. Kirchner et al., 2012). Additionally, ONIHL can present a limitation on the kind of employment suitable for a person with a hearing loss, (Thorne, 2006) which may possibly lead to economic burdens for developing countries in particular. It is argued that hearing loss represents a heavier burden in

developing countries than in developed regions of the world because of the challenges faced by developing countries when compared to their developed counterparts (Chadambuka et al., 2013). For instance, one of the biggest challenges in South Africa is that historically, Black mine workers were not given an opportunity to obtain formal education. Consequently, most workers in the mining industry are illiterate and are restricted to performing jobs that require manual labour as these jobs do not often require any form of education (Smit & Mji, 2012). According to the authors, this has lifelong implications for miners as they may not be employable due to illiteracy, and while hearing disability caused by excessive exposure to noise in the workplace may render them eligible for worker's compensation it may not be sufficient. Consequently, these workers will be eligible for state pension, thereby adding to economic burdens in a developing country. Therefore, averting these negative conditions associated with ONIHL is important for audiologists. Audiologists are knowledgeable in the management of ONIHL as detailed in their scope of practice (American Academy of Audiology, 2003). Therefore, they need to take an active role in minimising the impact of ONIHL on miners, and to promote and advise on the implementation of hearing conservation programmes in the mining sector.

In 2003, the Mine Health and Safety Council (MHSC) in South Africa, comprising the State, Labour and Employer representatives signed an agreement with the mining industry to target two imperative milestones in addressing ONIHL in the mines (Phillips, Heyns, & Nelson, 2007; Strauss et al., 2012) . The first was to eliminate hearing deterioration greater than 10% by December 2008 in individuals who are exposed to excessive occupational noise. The second was to minimise total noise emitted by any equipment to not exceed 110 dBA at any point in the workplace by December 2013. These milestones were reviewed and subsequently revised in 2014, as the mining industry did not meet these milestones. The revised 2014 milestones stipulate that:

a) by December 2024, the total operational or process noise emitted by any equipment must not exceed a milestone sound pressure level of 107 dB (A). b) By December 2016, no employee's Standard Threshold Shift (STS) will exceed 25 dB from the baseline when averaged at 2000, 3000 and 4000 Hz in one or both ears (MHSC, 2014). The failure to achieve the initial milestones created the avenue for researchers to conduct studies into how these milestones can be achieved.

After the failure to meet the 2003 MHSC milestones, the mining industry acknowledged that they are "not making the desired progress with noise-induced hearing loss, which is a major occupational health concern" (Booyens, 2013, p. 1). Furthermore, the mining industry stated that ONIHL is "prominent in the mining industry because action plans aimed at eradicating this disease are not as well integrated as they should be. We need far more comprehensive noise-control programmes" - however, the industry itself is committed to "the massive reduction and elimination of occupational noise induced hearing loss" (Booyens, 2013).

These assertions highlight the importance of conducting research in this area to ensure that preventative measures are in place, that early identification of those with ONIHL occurs, and that early intervention is instituted. This is particularly important because evidence exists that illustrates the impact of unmanaged ONIHL. Thus, in responding to these challenges highlighted by industry, independent researchers have embarked on conducting research into the mining sector with an aim to address these concerns. However, there seem to be challenges with allowing independent researchers access into the mines to conduct this integral research. The current study aimed to investigate the feasibility of conducting research into the management of ONIHL in South African large-scale mines. This study is part of a bigger study entitled "Occupational noise induced

hearing loss in South African large scale mines: from policy formulation to implementation and monitoring".

3.3 Methods

3.3.1 Research objectives

- To determine ease of identifying focal person in charge of hearing conservation programmes in the mines.
- To establish the response time and rate of identified focal persons for interviews regarding hearing conservation programmes in their mines.
- To explore focal persons' willingness to share information regarding hearing conservation programmes in their mines.

3.3.2 Research design

A qualitative research strategy comprising secondary and primary data was used for data collection and analysis. The study had two phases: online desk research (secondary data) and interviews (primary data). Phase one consisted of using a strategy for collecting data from existing online sources outside the researcher's organisation (Juneja, n.d.). Websites of large scale mines as well as private and public companies affiliated to the mining industry in South Africa were searched. This was done to investigate the ease of identifying different stakeholders responsible for managing ONIHL in the mining sector. Online research was conducted prior to inviting different stakeholders to participate in the study (Travis, 2016).

Phase two consisted of inviting focal persons identified from the online search to participate in interviews regarding the management of ONIHL in the mining sector. This phase of the study was concerned with determining the response rate and time of the focal persons approached for this

study as well as participants' willingness to participate in the study. A third phase was planned, involving obtaining access to the mines for audiology workplace assessments, but it never came to pass as access was not permitted.

3.3.3 Sampling strategy

Purposive sampling strategy was utilised as the researcher sought to identify and select individuals and groups of individuals who have experience and are knowledgeable on the management of ONIHL in the mining industry (Etikan et al., 2016). Furthermore, participation was completely voluntary, so willingness to participate was essential. Potential participants were identified from the mining industry as well as private and public organisations affiliated to the mining industry. These participants were selected based on their work titles and credentials as listed in their personal profiles on the company websites.

3.3.4 Description of participants

Three sets of participants formed part of the current study:

1. Large scale mines in South Africa

26 mines in South Africa were identified, 14 of which were large-scale mines. These mines produce different commodities such as gold, platinum, diamond, coal, heavy metal, and iron ore, and are situated in various provinces across South Africa.

2. Public organisation affiliated to the mines and the state

This organisation is a national public entity which consists of a tripartite board represented by state, employer, and labour members under the chairmanship of the Chief Inspector of Mines. It is

funded by public revenue and accountable to parliament. The main task of this entity is to advise the Minister of Mineral Resources on occupational health and safety legislation and research outcomes focused on improving and promoting occupational health and safety in South African mines.

3. Private organisation affiliated to the mines

This organisation, founded in 1894, is a non-profit insurance company. It is the administrator of workers' compensation claims, including the medical payment of medical costs, once-off disability payments, and the ongoing payment of pensions in the case of severe disability and death in the mining industry. Currently, there are approximately 26 mining companies under this administration.

3.4 Ethical considerations

Ethics clearance was obtained from the University of the Witwatersrand's Human Research Ethics Committee (Medical) (Protocol Number: M160264). Participants were provided with information letters detailing the purpose, nature and ethical considerations of the study. Participants were assured that all the information obtained from the interviews will be kept confidential. Secondly, any identifying information such as names or affiliated companies will be removed and or anonymised. Third, participants could withdraw from the study without any negative consequences. Lastly, anonymity was guaranteed as participants were identified by the researcher. However, in one case, an invited participant requested to bring along a participant who had occupied her current position. Both these participants completed consent forms. Participants signed consent forms, indicating agreement to participation. Permission to audio-record the nterviews was requested and obtained.

3.5 Data collection

For the first phase, data were collected through the use of a checklist containing the following categories: immediate availability of the focal person; their contact details; their occupation/title and their professional background. The information from the online research populated this list. For the second phase, data was collected through interviews. To record the response time and rate, and the focal persons' willingness to participate in the study, a logbook was used. The logbook recorded the first time contact was made, when a response was received, if the researcher had to follow up with participants due to no response and the date and time when the appointment was made. For telephonic interviews, the same information was recorded. Every contact and engagement between the researcher and the possible participants was captured in the logbook to supplement the field notes collected during the interview period. Therefore, a careful record of response time and response rate was key to identifying barriers.

3.6 Data analysis

Data was analysed using deductive thematic analysis as recommended by Braun and Clark (2006). This method was chosen because in deductive thematic analysis, the researcher predefines themes based on specific research questions and the researcher's specific area of interest (Braun & Clark, 2006; Gale, Heath, Cameron, Rashid, & Redwood, 2013), as was the case in the current study. All electronic communication, recorded telephonic responses, checklists and the logbook were essential data. The researcher followed an immersive approach to engagement with the data. Responses that pertained to ease of identifying focal persons, response time and rate and

willingness of participants to share information was assigned to predefined themes, which tie to the objectives mentioned above. These themes are reported.

3.7 Results

The findings of this study are reported according to the three sets of participants identified in this study as well as according to the objectives of this study which served as predefined themes.

Objective 1: Ease of identifying focal person in charge of hearing conservation programmes in the mines

1. South African large scale mines (SALSM)

The 14 mines included in this study were large-scale mines. From the online searches, it was found that only six of the 14 mines had a focal person listed online. Of the remaining eight, six listed no focal persons and the remaining two did not display the members or executive managers of the company.

With the six listed focal persons, it was not overtly documented that the identified person was indeed directly involved in the management of ONIHL or implementation of hearing conservation programmes. The assumption that they are somehow involved in HCPs was inferred from the occupational titles that they were given. For instance, some were listed as:

- Executive Member: Mining and Safety, Health and Environment
- Executive Vice President: Sustainable Development comprises the disciplines of Safety, Health, Environment, Social and Community Affairs, Human Rights and Global Security, and Government Relations

- Chief operating officer (Safety, mining projects, new development and corporate strategy)
- Group Executive: Health and Safety
- Executive Head-Safety and Sustainable Development
- The Safety, Health and Environment (SHE) Committee

It is worth noting that these focal persons are occupying important or key positions which allow them to influence and promote the success of a hearing conservation programme at their respective mines. Three of the focal persons identified had a background in mining engineering, one in biological sciences; while two had no backgrounds listed.

All the identified focal persons did not have their contact details listed with their names and occupations. One would need to contact the company's secretary telephonically or electronically to reach them. When the researcher attempted to contact the focal person through the company's provided email address, an automatic acknowledgement of receipt email was received, however, no responses were subsequently received from either the company's secretary or the focal persons identified. When the company was contacted telephonically, the calls were either unanswered or transferred to the focal person's personal assistant. The personal assistants generally stated that the identified focal person had a busy schedule therefore they will be unable to make time for interviews. Some personal assistants requested the contact details of the researcher with a promise to contact the researcher once the focal person was available. Unfortunately, no further contact was received. Consequently, none of the identified listed focal persons participated in this study.

Due to the fact that large scale mines are integral to this study, the researcher had requested help from the public organisations affiliated to the mines for assistance with identifying focal

persons who are directly involved with the HCP in the mines. To date, the researcher is still in contact with the large-scale mines requesting permission to access the mines and to invite focal persons to participate in the study through interviews.

2. Public organisation affiliated to the mines and the state (POMS)

This search identified 14 focal persons. Eight responded to the request to participate, but ultimately, only six gave interviews. The focal persons were identified with ease. The website listed all the members of this organisation and their affiliation: Labour, State and Employer. However, each individual's contact details were not provided. The researcher contacted the company's receptionist and requested the contact details of all the listed focal persons, and they was provided with the personal assistants' contact details. The personal assistants were able to provide email addresses of the focal persons. Following which, the identified focal persons were contacted electronically via email to invite them to participate in the study. Eight focal persons responded to the email indicating their willingness to participate in the study, and their interviews were planned. Face-to face interviews were conducted with five participants, and one participant requested a telephonic interview as they were unable to commit to a specific time due to the nature of their job. Two participants, requested to do the interview together. This arrangement was made as the second person had recently joined the company and they felt that they might not be in a position to answer all the questions which might require institutional memory.

Of the six participants, one was from labour, one from the State and four from the employer. As with the focal persons identified from the large scale mines, their roles as individuals were not stated. However, the mission and vision of the company itself was listed. Five participants

had a medical background before joining this organisation and still continue working in their capacity as medical doctors for various employers.

3. Private organisation affiliated to the mines (OAM)

Identifying focal persons from this organisation's website was difficult. It lists the board and executive members, and each individual's roles are listed on separate pages. The researcher read the profiles of all the persons listed under executive management, and was still unable to identify the focal person involved in the management of ONIHL in the mines. Furthermore, none of the listed executive managers had their contact details listed. The researcher contacted the organisation through the call centre number to request more details. The receptionist reported that they cannot provide the contact details of any staff member to the public. The researcher was advised to email the organisation's secretary and the email will be directed to the relevant person who will then contact the researcher. An email was sent to the provided address, and a response received, stating that the relevant person would send a reply. This was done twice, and on both occasions, other than the automatic response no further correspondence was received.

During the interviews with one of the participants from the public organisation affiliated to the mines and government, the researcher shared the challenges faced with finding participants. It was at this stage that this participant furnished the researcher with the contact details (cell phone numbers) of the two focal persons at the organisation affiliated to the mines. This participant first obtained permission from the focal persons before giving the contact details to the researcher. Following this, the researcher contacted the two persons from OAM telephonically and none of them responded. The researcher then opted to utilize short messages service (SMS) to contact them

and requested their email addresses. A few days later, one person responded with their email address. This person also has a background in medical science.

Objective 2: The response time and rate of identified focal person for interviews regarding hearing conservation programmes in their mines

1. **Large scale mines**

To date, it is rather difficult to report on the response rate of the large-scale mines as none of the mines have committed to participating in the study. It suffices to say that it is now over 18 months since the initial request to gain access to the mines to collect data was made, and still there is no response. This has led to having to explore other avenues to collect data for the main study. So far, only one mine committed to participate in the study; however, mine executives and managers have not participated in the interviews. This mine has however, partially furnished the researcher with some of the requested data. The discussions between this mine and the researcher are still ongoing.

2. **Public organisation affiliated to the mine and the state**

Contact with OAMS was initially initiated on 19 April 2016. After obtaining contact details, Table 1 below details the response rate in the current study.

3-1: - Table 1. Time period between initial contact to conducting the interviews

Participant	Affiliation	Responded first time round	Responded after follow-up	Type of interview	Total number of days
1	Labour	Yes	-	Face-to-face	12
2	Employer	Yes	-	Telephonic	16
3	State	-	Yes	Face-to-face	28
4	Employer		Yes	Face-to face and teleconference	51
5	Employer	-	Yes	-	51
6	Employer	-	Yes	Face-to-face	78

3. Private organisation affiliated to the mines

OAM was initially contacted telephonically in April 2016 to request the contact details of the focal persons. The researcher was advised to send the request electronically, using the company's email address. The email was sent the same day, after speaking to the company's secretary. The response was received immediately stating that the email has been received and will be forwarded to the relevant person. Exactly, 14 days later, in May 2016, the researcher sent another email to follow-up and requested another appointment. However, the same reply was received.

Upon realising that this response was an automatic reply, it became a likely probability that no response was forthcoming. After obtaining the contact detail of the focal persons at OAM, the researcher contacted the two focal persons telephonically in July 2016. One focal person responded immediately and provided the email address to which the researcher sent her request and invitation. The focal person also stated that they were away from the office.

Mid July, the focal person forwarded the researcher's email to the general manager. A week later, after not receiving a response from the focal person, the researcher sent a sms to check whether the focal person received the email. The focal person responded immediately stating that they received the email and were awaiting feedback from the General Manager. Later on the same day, the researcher received a response with an invitation to a meeting in the first week of August 2016. In total, it took 18 days from the initial positive contact with a focal person to having a meeting. These focal persons did not participate in the interviews.

Objective 3: The focal person's willingness to share information regarding hearing conservation programmes in their mines

1. **Large scale mines**

The researcher is still in contact with various mine focal persons to continue pursuing requests for permission to access the mines for data collection. Of the focal persons that the researcher was able to contact from the list provided by the Chamber of Mines, two focal persons categorically stated that they would not provide access. When pressed for reasons, one focal person stated that they have their own people conducting studies at their mine, so they will not allow any more researchers. The other stated that they were undergoing a restructuring process, so they will not be allowing any researchers into the mines. Another focal person indicated they were interested in allowing the researcher to conduct their study at the mine but needed to request permission from the management team. However, this focal person has not responded to follow-up emails since.

2. **Organisation affiliated to the mines**

No further engagements took place between the research and this focal person as they stated that the research should contact the mines directly to obtain the required information.

3. **Organisation affiliated to the mines and state**

Generally, at face value, some members seemed eager to share the information with the researcher; but there were restrictions to how much could be shared with the researcher. For instance, one participant requested that the researcher provides background information and involvement with the mines before agreeing to participate in the interview. After background was given, the focal person then participated in the interview. During the interview, the focal person shared some figures on the prevalence of ONIHL based on the report shared with the focal persons at the last health and safety summit. The researcher requested the copy of the report, and the focal person promised to send this to the researcher as soon as they returned to their office. A few days later, the researcher contacted the focal person again to request the report; and the focal person could not remember which document the researcher was referring to. This document has not been received to date.

The researcher was advised by one of the participants to search the internet for the documents. An internet search was conducted, but there were challenges with accessing most of the documents relevant to main study. This was due to the fact that one needs to be registered with different companies in order to have access to files. Therefore, these files were not obtainable. This issue was mentioned to one participant, and they responded, "if one found answers easily, there would not be a point in doing research. It is called research because you have to do some searching."

Another participant requested to do a telephonic interview provided the researcher sent them the interview questions electronically to preview the content of the interview before providing consent. The researcher informed the focal person that this was not possible. This participant then requested to have a face-to-face interview after office hours as they were unable to find a suitable

time during office hours. Also, this participant stated that they wanted to see the person they were giving the information to. During the interview, the participant mentioned their weariness with sharing information with researchers as researchers often misinterpret the data and quote people out of context. Furthermore, this participant requested a copy of the completed thesis to verify the content of the report. One more participant requested to be sent the questions in advance in order to prepare for the interview.

3.8 **Discussion**

Current results illustrate the difficulty with identifying focal persons involved in the hearing conservation programmes in large-scale mines in South Africa. This is further exacerbated by the fact that, even where the focal persons are listed, their positions simply list the general health and safety position with their exact role in the management of noise not overtly stated. This is deemed a challenge, Byrne (2005) asserts that the first step mines should consider before implementing a hearing conservation programme is addressing administrative issues where company regulations or policies are clarified, and where individuals' responsibilities and roles are identified and enforced. The roles and the responsibilities of individuals should be listed on the company's website for the ease of contacting the relevant persons should the need arise.

From current results, it was noted that of all the focal persons identified in this study, none had a background in audiology. Arguably, the fact that participants either had a background in mining engineering or medical sciences might imply that they may have some knowledge about the impact of noise on the wellbeing of individuals exposed to excessive occupational noise. However, evidence suggests a need for focal persons with a background in audiology. The

American Academy of Audiology suggests that the audiologist is the principal advocate for and supervisor of programs that manage the hearing health of people exposed to hazardous noise (American Academy of Audiology, 2003). This is based on the training and scope of practice of audiologists which states that "the audiologist designs, implements, and coordinates occupational and community hearing loss prevention programs which includes identification and amelioration of noise-hazardous conditions, identification of hearing loss, recommendation and counselling for use of hearing protection, employee education, and the training and supervision of non-audiologists performing monitoring audiometry in the occupational setting" (American Academy of Audiology, 1997; 2003, p. 1). This highlights the important role that audiologists should have in the key positions in the management of noise induced hearing loss in the mines.

The fact that all the focal persons identified occupy key positions in the executive management at the mines is an important finding. This indicates the importance mines seem to place on occupational health and safety; and it also suggests that these individuals are in strategic positions where they are able to advocate and promote hearing conservation programmes at the mines.

As far as the response time and rate of identified focal persons, current findings were disappointing. The results revealed that the minimum timeframe from initial contact to the when the interviews were conducted is a minimum of 12 days, with maximum at over 18 months. This is a concern for researchers as in most cases, cross-sectional studies are conducted within fixed time frames. Delays in obtaining data timeously affect the quality and the completion of the study. This poor response time and rate also raises implications for prompt and efficient evidence-based interventions to reduce or eliminate ONIHL in the mines. An evidence base that is both

contextually relevant and contextually responsive is essential and so engagement in objective research that has minimal to no conflict of interest is important for mines to engage in to use best practice in HCPs instituted in the mines. This willingness to engage in objective research was demonstrated to be minimal.

As far as focal person's willingness to share information regarding hearing conservation programmes in their mines, current findings indicated that the identified focal persons are guarded when it comes to sharing information. The fact that participants wanted pre-access to the interview questions and also wanted to approve reports written about the study indicated some level of high anxiety and suspicion about the type and nature of information they can or cannot share, and a demonstrated fear of revealing information that might be deemed damaging to the individuals concerned or to the company. This restriction in information might have a significant impact in reality-based planning where real and accurate evidence is used to plan efficacious interventions.

3.9 Conclusions

Current findings regarding the ease of identifying and accessing focal persons involved in hearing conservation programmes in various large-scale mines in South Africa highlight the challenges faced by researchers in identifying and gaining access into the mines. This has implications for the mines as these findings suggest that focal persons are not easily identifiable and their roles are not clearly stated. Furthermore, the majority of the focal persons do not respond (promptly) to requests for engagement is concerning as opportunities to share information and knowledge on the management of noise induced hearing loss in the mines are lost and deliberations on efficacious HCPs reduced. Sharing of such knowledge may assist in identifying the factors that contribute

both positively and negatively to the success of the hearing conservation programmes in various mines. Lastly, the fact that some participants requested to pre-view the interview questions creates the perception that there is certain information that should not be made available to the researchers or interested parties. Such practices may hinder the success of hearing conservation programmes as information deemed confidential may not be shared, impacting negatively on the success of hearing conservation programmes in large scale mines. This potentially evidences a lack of understanding of ethical research practice that is commonplace in academia and adherence to tenets of confidentiality and anonymity.

These findings highlight the importance of clearly demarcated and documented roles of key members in charge of HCPs; with clear communication lines. Findings indicating the minimal or absent role of audiologists in hearing and ear-specific occupational health within the South African mining industry raise important concerns which the Health Professions' Council of South Africa and the Department of Labour might need to deliberate on for future planning around noise pollution and the role of audiologists in the management of noise in the work place.

In conclusion, the authors do acknowledge that managers of private and public organisations are at liberty to resist independent investigations of health and safety hazards faced by their employees in the workplace. However, current findings can potentially make management appear derelict in their responsibilities towards their employees in the management of noise. These findings might even pressure regulatory agencies to enforce regulations in the mining sector regarding transparency and ease of access to information for researchers. Such outcomes may be unpleasant from a management point of view, but, for HCPs to achieve their goal, such findings are important to share.

It is anticipated that all stakeholders involved in HCPs, and possibly other programmes relating to other health and safety concerns in the mines, will deliberate on the challenges presented in this paper and identify how these could be contributing to their inability to reduce and/or eliminate health hazards in the workplace. It is also hoped that this paper will spark debate within the mining sector about the reasons for the position of "in-house" research that seems to be prevalent, and how this could be (negatively) influencing their goals and targets with regards to health and safety.

3.10 **Data availability**

The purpose of this paper was to communicate the feasibility of conducting research into the management of ONIHL in South African large-scale mines. The focus was on identifying focal persons in charge of hearing conservation programmes, establishing response time and rate of focal persons to participate in interviews and the participant's willingness to share information regarding hearing conservation programmes. Data from the interviews is not provided as the findings of this study do not include the content of the interviews to answer any of the questions posed above. Furthermore, personal electronic correspondence between the researcher and stakeholders will not be made available to the public as it was of a personal nature. It was used to create a logbook for analysis. Therefore, only data in the form of checklists and the logbook is available (please contact the corresponding author).

CHAPTER 4. THE MANAGEMENT OF OCCUPATIONAL NOISE INDUCED HEARING LOSS IN THE MINING SECTOR IN AFRICA: A SYSTEMATIC REVIEW- 1994 TO 2016



HEARING PROTECTION: A SOUND INVESTMENT

(Kansas Teaching Standards for Hearing Protection, n,d,)

The management of occupational noise induced hearing loss in the mining sector in Africa: a systematic review- 1994 to 2016

(Reprinted with permission, see appendix H)

4.1 Abstract

Literature into exposure to occupational noise in developing countries suggest that the prevalence of occupational noise-induced hearing loss (ONIHL) is still high. There is also evidence that the mining industry is aware of this epidemic; however, the efforts to curb ONIHL are currently unsuccessful. Therefore, the aim of this study was to explore and document current evidence reflecting trends in the management of occupational noise-induced hearing loss in the mining industry in Africa from 1994 to 2016. A systematic literature review was conducted in line with the Cochrane Collaboration guidelines and Preferred Reporting Items for Systematic Reviews and Meta-Analysis. Electronic bibliographic databases such as Science Direct, PubMed, and Scopus Medline were searched. A total of 1212 titles and abstracts were identified; of which only nine papers formed part of this study. The results indicated that there is a dearth of research on the management of ONHIL in Africa. The limited research on the management of ONIHL focuses on some aspects of hearing conservation programme pillars and not on all the pillars as suggested by some scholars in the field. Furthermore, these studies had small sample sizes; thereby minimizing their generalization. There is therefore a need for more studies on the management of ONIHL in the mining sector as there is evidence to suggest that ONIHL in African countries is still on the rise.

Key words: Developing countries, hearing conservation programmes, hearing loss, mining industry, occupational noise

4.2 Background

The South African Mine Health and Safety Council (MHSC)(Mine Health and Safety Council, 2016) states its goal as "every mine worker returning from work unharmed everyday: Striving for zero harm". As far as ear and hearing health, this goal, however, has not been realized despite the concerted efforts from the MHSC and the Chamber of Mines in South Africa. The reality is that approximately 73.2% of miners in South Africa are exposed to excessive noise surpassing the legislated occupational exposure limit of 85dBs, despite hearing conservation programmes (HCPs) implemented in the mining sector. (Edwards et al., 2011; Strauss et al., 2012). HCP are multi-component interventions aimed at managing noise induced hearing loss in a workplace (Seixas et al., 2011). Well-integrated and comprehensive HCPs are those that encompass all seven pillars namely: periodic noise exposure monitoring, engineering controls; administrative controls, personal hearing protection, audiometric evaluations and employee/ management education and training and record keeping (Hong et al., 2013). Amedofu and Fuente (2008) argue that the success of HCPs depends on the implementation of all the pillars of the conservation programme.

Numerous studies have been conducted to evaluate the effectiveness and efficacy of management of ONIHL within the South African mining industry. These studies have yielded unfavourable findings, which indicate that significant efforts are still required to successfully manage ONIHL (Edwards et al., 2015; Edwards & Kritzinger, 2012; . Dekker, Edwards, Franz, . van Dyk, & A. Banyini, 2011) Published evidence indicates that the prevalence of ONIHL is high in developing countries such as South Africa. Storbeck and Moodley (2011) maintain that hearing loss represents a heavier burden in developing countries than in developed regions of the world because of the challenges faced by developing countries when compared to their developed counterparts. Moreover, ONIHL can present a limitation on the kind of employment suitable for a

person with a hearing impairment, which may possibly lead to economic burden for developing countries in particular. Establishing the status of ONIHL and its management in developing countries becomes important if strategic planning around this occupational health challenge is to be systematic and successful. It is therefore with this backdrop that this study was conceptualized. This study aimed to explore and document current evidence reflecting trends in the management of ONIHL in the mining industry in Africa.

4.3 Methods

4.3.1 Data sources and literature search

To identify studies reporting the management of ONIHL in the mining industry in Africa, a systematic literature review was conducted in line with the Cochrane Collaboration guidelines (Higgins & Green, 2011) in conjunction with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). The electronic bibliographic databases that were searched included Science Direct, PubMed, Scopus Medline, ProQuest and Google scholar. The search terms used (PubMed Mesh terms) included "occupational noise induced hearing loss", "occupational noise AND hearing loss", "work- related noise" OR "hearing loss" OR "hearing impairment" OR "disability", "noise in the workplace" AND "Africa" OR "African" OR "sub-Saharan Africa" AND "management" OR "managing" OR manag* "addressing" OR "intervention" AND 'mining" "min*"

4.3.2 Inclusion Criteria

Articles selected for inclusion in this study were original pieces of scientific work or reports published in peer-reviewed scientific journals. These articles were conducted in the mining sector

in Africa between January 1994 and December 2016. The focus was on the management of ONIHL in the mining sector in Africa. All the articles were published in English.

4.3.3 Data extraction and synthesis

First, articles to be selected for inclusion were independently identified by four investigators (N.M., K.K.-S, A.K. and L.N.) using pre-defined abstraction. Disagreements on papers selected for inclusion were resolved through discussion and consensus among all four researchers. Where consensus was not reached, N.M. as the leading author made the final decision. Second, authors provided a narrative synthesis of the findings from the studies that met the inclusion criteria. The synthesis included the study objectives, study design, study setting and management strategy used in the included studies.

4.4 Results

4.4.1 Study identification

A sum of 1212 titles and abstracts were identified, from which 1195 were identified from the databases mentioned previously and 17 manual reviews of the reference lists of the identified publications. A total of 798 titles and abstracts were excluded due to duplication. Around 414 abstracts were screened and 377 were removed post abstract review, as they did not meet the criteria in terms of being conducted in the mining sector in Africa. Consequently, only 37 articles were subjected to a full-text review, of which 28 were excluded as they were not original research articles or peer-reviewed. Eventually, a total number nine studies were eligible for inclusion in the study. Of the nine articles reviewed, two focused on the use of engineering controls; one on

administrative controls; four on the use of personal protective devices, and one on education and training as a means of eliminating ONIHL in the African mines. Figure 1 presents the PRISMA flow diagram describing the process of study selection. The findings of each selected study were reviewed and synthesized qualitatively, as there was substantial heterogeneity among the studies reviewed.

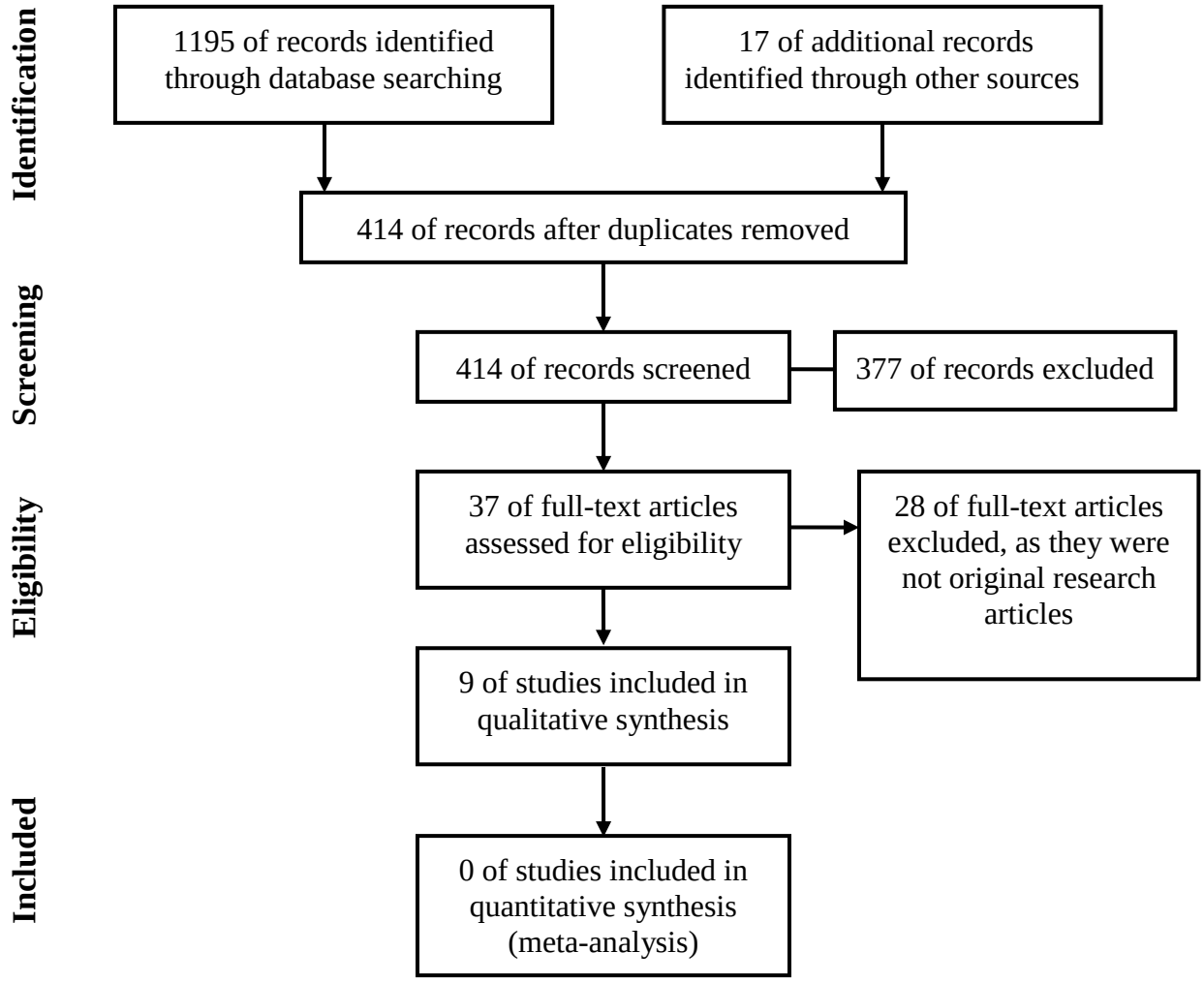


Figure 3: - The PRISMA flow diagram describing the process of study selection

4.4.2 Studies Characteristics

4-1: Table 1 - Describes details of study characteristics of each included study

Author(s) & Date	Research title	Research focus/aims	Methodology	Context	Results
Edwards, AL Milanzi, LA Khoza, NN Letsoalo, MS Zungu, LI (2015)	Evaluation of the current practices of noise-induced hearing loss (NIHL) awareness training in the South African mining industry	Evaluation of practices of mining companies in relation to the criteria for best practice of NIHL awareness training	Descriptive survey design. Questionnaires followed by interviews with managers responsible for HCPs	Six mining companies in South Africa- national representation. 30 managers were interviewed.	No commitment to NIHL training by all mines. No theoretical basis for NIHL awareness training. More than half of the mines did not evaluate the employee's knowledge after training. No measure of whether the training is effective or assisting with achieving specific goals
Gumede, H., Blomerus, K.; Coutts, D & De Beer, J. (2014)	Strategy towards a mining industry-wide Buy-and-Maintain Quiet	To identify the factors on which the success of a Buy quiet initiative will depend- an	Workshops using obstacle based planning techniques	South African mining industry	Number of obstacles preventing implementation of BQI. Lack of involvement by relevant stakeholders. Poor collaboration in the industry. Poor scoping in terms of having dedicated task teams

	initiative to reduce noise induced hearing loss	initiative aimed at reducing NIHL by reducing noise at its source.			
Ntlhakana, L; Kanji, A; Khoza-Shangase, K; (2015)	The use of hearing protection devices in South Africa: exploring the current status in a gold and a non-ferrous mine	To investigate mine workers' current use of HPDs in South African gold and nonferrous mining subsectors; to determine factors influencing the use of HPDs and their relationship to gender, level of education and years of	Descriptive study design. Face-to-face structured interviews were conducted, using a self-developed questionnaire	Gold and non-ferrous mines in South Africa	Every miner was provided with HPDs, but disposable-chorded foam earplugs were observed to be used by the majority of participants. Majority of participants stated that they used HPDs at all times during the 8 to 10 hours shifts. The reduction of the risk of hearing loss and protection from loud noise exposure; and reduction of dust contact with the ear canal were reported as benefits of HPD usage. Factors related to comfort, design and ability to manage work-related communication and warning signals influenced HPD usage

		experience; and to determine factors associated with the use of HPDs in these workers.			
RJ Steenkamp (2008)	A personal approach to hearing conservation: the key to effective second-level noise control	To determine current HPD status and developments and to investigate the current trend to use custom-made HPDs for personal hearing protection as a catalyst for	Web-based survey design using a self-developed Likert scale questionnaire	Manufacturing and mining companies in SA	Nearly all respondents (87%) anticipate that HPDs will become a more important means of hearing protection. Respondents indicated a clear need for improvement in the standards of HPDs used. The best and preferred HPDs are the custom-made types. 78% of respondents agreed that each worker will need to be managed individually, custom fitted with an appropriate HPD, personally trained and serviced (at least once annually). Comfort was the most frequently chosen minimum standard

		personal hearing conservation.			(97%), followed by hygiene. Yet when forced to choose ONE only of the above, signal detection increased. Comfort and user-friendliness were noted for improved HPDs.
Amedofu, Geoffrey Kwabla;	Effectiveness of hearing conservation program at a large surface gold mining company in Ghana.	To determine the effectiveness of a Hearing Conservation Programme (HCP) was conducted in a surface gold mining Company in Ghana.	Retrospective review and comparison of individual audiograms from 1999-2003	Large surface Gold Mining Company in Ghana	Out of the two hundred audiograms, which were examined, 11 (5.5%) showed an increase in thresholds of more than 10dB (i.e. indicating worsening hearing levels) while 3 (1.5%) showed a decrease in thresholds (i.e. hearing levels showed an improvement)

Mutara, G. & Mutanana M (2015)	An Analysis of a Hearing Conservation Programme (HCP) at a Mining Company in Zimbabwe	The study sought to carry out an analysis of a hearing conservation programme at a mining company in Zimbabwe.	A mixed mode approach in which both qualitative and quantitative paradigms were used. The quantitative aspect entails obtaining quantitative data through questionnaires' The qualitative approach entails data collection using in-depth interviews.	Mining company in Zimbabwe.	the mine under study is providing Hearing Protective Devices and the majority of the workers are making use of them. However, it would appear the HPD conservation programme is suffering a setback from some employees who do not want to use them, for instance General Hands and Artisans. None of the workers are using the dual protective method, a standard that is recommended by several researchers. The researchers observed that the company is doing well in carrying out audiometry tests during annual medical examinations. To this end, the medical interval has been found to be adequate for the employees.

Steenkamp (nd)	A six sigma-based management model to eliminate the noise-induced hearing loss pandemic in South African mines	To contribute towards best practice ISO hearing conservation programme standard by revisiting hearing conservation, existing HCP models, new trends and eventually addressing the weaknesses of current hearing conservation practice in South African mines. To present a hearing	Research methodology using several measuring instruments in a combination of personal qualitative observation, empirical evidence, theory and quantitative description. The six sigma methodology based on secondary research and a case study	South African mining industry	The six sigma model is a powerful model that can serve as a quality management of HCPs and assist in managing NIHL. It is beneficial when looking at personalized aspects of HCPs such as custom made HPDs. The model requires that each dimension of the HCP model be subjected to measurement. These dimensions include audiometric testing and monitoring of NIHL using objective measures as well; worker orientation and education related to HP; optimal and appropriate HPDs that are custom made; utilization of HPDs by workers

		conservation model as a foundation for future research.	from a platinum mine.		
Hansia & Dickinson (2010)	Hearing protection device usage at a South African gold mine	To determine the actual and reported use of hearing protection devices (HPDs) in noise-exposed gold mine workers and their reported knowledge,	A cross-sectional descriptive study was conducted in which 101 noise-exposed mine workers were interviewed and their use of	South African mining sector	The majority of participants correctly indicated that they worked in noisy environments, that their noise exposure could damage their hearing and that HPDs are beneficial. Reported use (93%) was notably higher than the observed use (50%). The higher the skill level, the greater the proportion observed using HPDs. Reasons for not using HPDs included discomfort, interference with hearing warning signals, HPDs not working or falling

		attitudes and practices relating to NIHL and HPDs.	HPDs observed.		out of the ears. Eight percent of respondents indicated that they were never informed about the benefits of HPDs.
Burger, NDL; Von Wielligh, AJ; De Wet, PR; Otterman, RW; Steyn, JL; (2004)	Design and development of a low noise rockdrill	Development of a low noise rock drill system.	functional analysis	South Africa	Noise levels of under 90 dBA were achieved, thereby attaining the primary design specification.

4.4.3 Study designs

Four studies used cross-sectional descriptive research designs where structured questionnaires and face-to-face interviews, and observations were used to collect data. One study used a retrospective record review of audiograms to analyse the efficacy of an HCP, while another study used multiple measures of personal qualitative observations, empirical theory evidence and quantitative descriptions. One study used a web-based survey design; another used functional analysis; while another used workshops utilizing obstacle-based planning techniques (Table 1).

4.4.4 Study settings

Of the nine studies included, seven were conducted in mining contexts in South Africa, while of the remaining two; one was conducted in Ghana and the other in Zimbabwe.

4.5 HCP pillar targeted as a means to manage ONIHL in the mines

The reviewed studies focused on four of the seven documented pillars of successful HCPs. These pillars included engineering controls, administrative controls, personal protection devices, as well as education and training. Current findings on these four pillars are presented in this order below.

1. Engineering controls

Two studies focused on the use of engineering controls as a means to reducing noise at its source in the mining industry. First, in a study by Gumede et al. (2014) development of a proposed strategy and structure for the buying quiet initiative (BQI) was investigated. This initiative focused

on adopting and promoting the use of quieter machines as a strategy of controlling noise at its source. Findings of this study highlighted that the mining industry does acknowledge BQI as a proactive strategy that will significantly reduce ONIHL and improve the management of noise at its source. However, this study also identified a number of obstacles in the implementation of BQI. The most serious obstacle concerned the formation of a well-constituted industry-wide task team which should include various representatives from relevant and key industry stakeholders. Furthermore, concerns regarding proper scoping, management leadership and the mining industry's adherence to the initiative were raised. Moreover, lack of involvement by stakeholders as well as economic constraints were also identified as potential obstacles in the implementation of BQI.

Second, in a study by Burger et al. (2004), the focus was on developing a low noise blast hole drilling system in order to reduce the risk of ONIHL in the mining operations. The rationale for this study highlighted the benefits of using this drill, such as removing the operator from the areas of excessive noise and minimizing the need for operators to support the drill thereby eliminating the risk of vibration-induced injury. Results from this study indicated that the developed low-noise rock drill achieved the noise level specification as stipulated in the legislation, thereby enabling the mining industry to be compliant with the ONIHL regulations.

2. Administrative controls

Of the studies reviewed, only one study focused of administrative controls. This study was conducted by Steenkamp (nd) and aimed to contribute towards best practice according to the International Standards Organization (ISO) with regards to implementing HCPs in the mines.

Therefore, this study revisited existing HCPs to report on the trends in order to address the weaknesses of current hearing conservation practices in South African mines. This study presents the six-sigma model, which seems to be a useful model that can serve as a quality management tool of HCPs and assist in managing ONIHL. It advocates for personalized aspects of HCPs such as custom-made hearing protection devices (HPDs). Implementing this model requires that all the pillars of the HCP be subjected to measurement. These measurements should include audiometric testing and monitoring of ONIHL using objective measures as well; worker orientation and education related to HCP; optimal and appropriate custom-made HPDs, as well as consistent use of HPDs by workers.

3. Hearing Protection Devices (HPDs)

Four studies focused on the use of HPDs as a means of managing ONIHL. While these studies indicated that the use of HPDs is a preferred method; there were challenges associated with the use of HPDs in the mines.

First, Ntlhakana et al. (2015) conducted a study in the gold and non-ferrous mining subsectors in South Africa and focused on the use of HPDs in the workplace. A total of 90 mine workers from the two mines (Gauteng province: 65 and Limpopo province 25) were interviewed using a questionnaire with open and close–ended questions. Direct observations were incorporated in this study where underground miners were observed to verify if they used HPDs when working in noisy places. Findings of this study confirmed the ineffectiveness of the HCP as far as use of HPDs was concerned. All the participants in the study reported using HPDs; however, comfort, design, and work-related communication were identified as barriers to poor and inconsistent use

of these. Also, the authors specifically reported that participants were aware of the importance of protecting and preserving their hearing, however, this was not motivation enough to use HPDs; therefore, prompting the need for more focused education on the impact and implications of exposure to hazardous noise levels in the workplace.

Second, in a study conducted by Hansia and Dickinson (2010) the actual and reported use of HPDs by participants exposed to excessive noise at a gold mine was explored. Furthermore, this study assessed the workers' reported knowledge, attitudes and practices relating to ONIHL and HPDs use. This study consisted of 101 participants who were interviewed and observed during their work shifts. The authors reported that some participants (13%) erroneously indicated that their workplaces were not noisy while 16% did not think that noise was a hazard in the workplace and 6% were not aware of the importance of using hearing protection when exposed to excessive noise. Around 3% reported that they believed the HPDs did not protect hearing. In this particular study, while the majority (n=93) of the participants reportedly used HPDs, only 50% were observed using their HPDs consistently. A small number (8%) of participants reported that they were not informed about the benefits of using hearing protection despite being informed. The authors reported that the participants claimed that HPDs were uncomfortable; hence their poor adherence to their use. Around 57% preferred other training methods other than the current computer-assisted training. However, the other preferred methods are not listed.

Third, in a study by Steenkamp (2008) the aim was to determine the occupational effects of quality hearing protection in terms of health, safety and productivity. Moreover, this study also documented the testimony and the experiences of using a custom-made hearing protection device (CHPD). Findings in this study revealed that workers used their CHPDs, and this was recorded as a great improvement when compared to standard HPDs use. The results also reinforced that

CHPDs are a preferred choice in terms of the workers' medical and occupational hygiene hearing ability status. Furthermore, CHPDs improved work in terms of quality, safety and productivity. Additionally, the workers who were fitted with CHPDs expressed satisfaction with this type of protection.

Finally, the fourth study by Mutara and Mutanana (2015) aimed to analyse an HCP at a mining company in Zimbabwe. This study consisted of 120 employees who completed individual questionnaires and took part in a focus group discussion. Findings of this study indicated that the company provided HPDs (plugs, noise-ban customized hearing devices and earmuffs) to their employees and that the majority of the employees used the HPDs to protect their hearing. Furthermore, in this study, the company conducted annual audiometric testing for all employees. However, there were setbacks identified as some of the employees did not use their HPDs despite having been educated on the how and the why of using hearing protection. This prompted the authors to recommend that the company should enlist the services of a resident audiologist to assist non-compliant employees.

4. Education and training

Edwards et al. (2015) conducted a descriptive survey to evaluate ONIHL awareness training programmes in 6 mines in South Africa. Findings of this study, firstly, indicated that there was lack of prioritization of commitment to awareness training, and that this challenge received little priority in all the participating mines. Secondly, findings revealed that a large majority of the mines (80%) lacked a solid and consolidated theoretical basis for their awareness training programmes. Thirdly, language used during the awareness training seemed to be an influencing factor where

there did not appear to be a standard language policy followed. In this study, the awareness training programmes were conducted 30% in English only, 40% in the employees' language of choice, and 30% combined English and Zulu. Lastly, findings from this study revealed that 60% of the participating mines did not evaluate employees' acquired knowledge post training.

5. Audiometry evaluation

Amedofu (2007) sought to examine the effectiveness of a HCP in a large surface gold mine in Ghana. In this study, a retrospective review and comparison of mineworkers' audiograms from 1993-2003 was conducted. Two hundred (200) mineworkers participated in this study. According to this study, the implementation of HCP was introduced in 1999 at the research site. The results revealed that hearing loss worsened in 5.5% of the participants, while in 1.5%, hearing function improved. The authors concluded that evidence from their study indicated that the HCP implemented in Ghana was effective as over 90% of the participants did not present with further hearing loss during their study. The conclusion from this study seems to have been solely based on the audiograms obtained from the mining company and data were collected from one large-scale mine with only 200 audiograms having been evaluated. This identified limitation in the methodological design of the study suggests that concluding that HCP was effective based on such a small population may have been premature and a similar study with a larger sample may yield more accurate results.

4.6 Discussion

The current review study identified nine studies which met the inclusion criteria for the systematic review. The studies that were selected were heterogeneous; therefore, attempts were not made to conduct a quantitative synthesis or meta-analysis.

Although ONIHL is not life threatening, unmanaged hearing loss may have a profound impact on the quality of life of the affected individual (Chadambuka et al., 2013) as ONIHL is irreversible and untreatable as the hair cells, once damaged, cannot be restored (Hong et al., 2013). However, ONIHL is preventable through a systematic and comprehensive effective HCP that includes all eight pillars of HCPs (Amedofu, 2007; Hong et al., 2013).

During the current study's qualitative synthesis, it was noted that no single study attempted to comprehensively and holistically address all the pillars of a HCPs in the mines. Current authors believe that the failure of conducting comprehensive and holistic studies may be attributed to the fact that HCPs are complex programmes or complex interventions with multiple and multifaceted component/pillars conducted in complex environments with various sources of noise and various stakeholders. Conducting such comprehensive studies may be time consuming; and may require significant resources and commitment from different stakeholders. Regardless of these challenges, current authors believe that if the South African mining industry is fully committed to the elimination of noise and its impact in the mining industry, such studies will need to be conducted to ensure that interventions yield successful HCPs.

Studies reviewed in the current study only focused on four pillars, in a piecemeal fashion; namely engineering controls; administrative controls; personal hearing protection; and education and training. These studies neglected periodic noise exposure, audiometric evaluations and record

keeping. Overlooking periodic noise exposure monitoring has implications for the entire programme as this pillar serves to identify individuals exposed to excessive noise in the workplace (Workplace Safety and Health Council, 2014). According to the Workplace Safety and Health Council (2014) noise monitoring should be conducted every time any alterations are introduced and applied on the machines or every three years, if there are no changes introduced in the workplace.

Another pillar that was not featured in any of the studies reviewed was record keeping. To maintain accountability, effective record keeping is crucial and it requires commitment and consistency, as, ONIHL develops gradually and overtime, therefore keeping records of each employee becomes crucial as records can be used to determine the employee's exposure to noise (Byrne, 2005). Proper record keeping allows for effective and accurate programme evaluation which is important for programme sustainability if successful; and/or programme changes where challenges are identified (Byrne, 2005). Proper record keeping also allows for accurate and appropriate individual conservation programme implementation where employees' compounding factors such as concomitant exposure to other toxins (e.g. co-occurrence of TB and HIV with ototoxicity) can be taken into careful consideration in employee HCP plans. Furthermore, proper record keeping allows for accurate comparative analysis of employee thresholds for compensation purposes; should this eventuality comes. Proper record keeping also facilitates accurate research to be conducted to allow for relevant evidence-base that can be accessed by the mining industry to enhance their HCPs.

With regard to the pillars that were targeted in the included studies, majority focused on the use of personal hearing protection. While some authors have argued that HPDs remain the most used method of prevention of ONIHL despite their limitations; they also emphasize that

HPDs are fully effective when used in conjunction within a comprehensive HCP (Berger, Franks, & Lindgren, 1996; Brink, Talbott, Burks, & Palmer, 2002; Davies et al., 2008; Rabinowitz, Galusha, Dixon-Ernst, Slade, & Cullen, 2007 ; Seixas et al., 2011; Toivonen, Paakkonen, Savolainen, & Lehtomaki, 2002).

However, the Department of Minerals and Energy in South Africa (DME, 2003) strongly recommends that the use of personal protection devices should be regarded as the last resort if engineering and administrative controls and audiometric evaluation measures fail. Current evidence, however, suggests that there is an over-reliance on hearing protection devices in the workplace (Bruce, 2007; Bruce & Wood, 2003; Hong et al., 2013; Suter, 2012). This was also evident in the current study as evidenced by the majority of the studies that focused on HPDs. Furthermore, it should be highlighted that there are challenges associated with the use of HPDs such as discomfort, negative impact on work-related communication and the design of the HPDs as was reported by the studies included in this review. Several authors Ntlhakana et al. (2015); Suter (2012); Tak et al. (2009) support that these challenges impact on compliance and adherence to using HPDs. These findings have profound implications for industries that do not use HPDs as part of a comprehensive HCP as they imply that workers who find their HPDs uncomfortable, they will expose themselves to hazardous noise in the absence of other effective HCPs measures protecting their ears against noise injuries. Therefore, it is also the view of the current authors that HPDs; although they have seemed to minimize the amount of sound energy to the ear, should be used in conjunction with the engineering and administrative controls – and not as a primary strategy.

It is encouraging that three studies conducted in this review focused on the use of engineering and administrative controls to combat noise in the mining industry. Conducting such

studies is critical as engineering and administrative controls are the first line of defence against exposure to loud noises (D. C. Byrne, 2005; University of New Hampshire, 2014). The ideal goal is to reduce the noise levels at the source of noise so that other elements of the HCP are not needed (Byrne, 2005). The benefits of implementing administrative controls and engineering controls include "permanence, effectiveness with or without worker/supervision compliance, less absenteeism, easier communication, lower worker compensation costs, and reduced legal costs" (Bruce, 2007, p.33). For engineering and administrative controls to be effective, management has a responsibility to make sure that noise sources that can be controlled through these controls are identified and prioritized and that the resources are allocated accordingly (Geigle Safety Group, 2012). The results of the current study highlighted the benefits of implementing engineering and administrative controls; however, they also highlighted the obstacles such as lack of commitment from management and poor formation of key task team members. According to Patel et al. (2010) the lack of enforcing regulatory requirements in the workplace is the major downfall to the success of engineering controls. In addition, there is a misconception that implementing noise controls is too arduous and costly, hence the lack of synchronized distribution of information regarding the importance of noise controls in the workplace. (Bruce, 2007). Although the argument of noise controls being too costly is legitimate; current authors believe that this cost is a once off monetary cost as opposed to the significant benefits to the health and quality of life of employees in the immediate and long run. The benefit also includes the elimination of compensation costs, which might increase significantly in the future with improved employee awareness of their rights as well as health and safety regulations,

Victor Hugo, a French author and playwright once stated that "No cause can succeed without first making education its ally" (Heath, 1982, p.6). These sentiments were highlighted by

the studies included in the current review (Edwards et al., 2015; Mutara & Mutanana, 2015; Ntlhakana et al., 2015). Patel et al. (2010) reported that most of the barriers experienced by the miners can be addressed by simply educating and training them on the importance of preserving their hearing. Stanton (2003) rightfully emphasized the importance of educating, not just the miners but the management also on hearing conservation practices. Education and motivation are a priority in minimizing hearing loss in the mines as they create opportunities for both management and employees to discuss and agree on commitments, communication lines and cooperation (D.Byrne, 2005). Training can be conducted to explain various and pertinent topics such as the effects of noise on hearing, as well as the purpose and value of wearing HPDs. In a training program, advantages and disadvantages of hearing protectors being offered by the company can be discussed in detail. Also, this may serve as an opportunity for highlighting the miners' and the operators' responsibilities in maintaining noise controls, while also describing the purpose and the value of audiometric testing (Byrne, 2005). If individuals understand the reasons and the benefits of a HCP, they are more likely to participate, especially if training addresses the specific needs of individuals exposed to excessive noise.

Current authors strongly concur that all the stakeholders and policymakers involved in the management of ONIHL should be trained in the long-term impacts and effects of ONIHL regardless of whether these stakeholders and policymakers are exposed to noise or not. This is especially true for management and employers who may not be directly exposed to noise as knowing and understanding the impact of noise may guide the stakeholders and policymakers in implementing HCPs that are realistic and relevant.

Although one study focused on the use of audiometry surveillance as a means of monitoring employee's exposure, it should be noted that this study was based on archived record reviews. This is not in line with the Occupational Health and Safety (OSHA) standards. According to OSHA (2002) audiometric evaluations are conducted to monitor an employee's hearing status over a period of time; as they play an important role in the HCP. They help identify employees who may be at a risk of developing occupational hearing loss (Workplace Safety and Health Council, 2014). Audiometric evaluations serve as an early detection process since the symptoms of hearing loss do not readily manifest until a significant threshold shift occurs (Workplace Safety and Health Council, 2014).

For effective evaluation; audiometric evaluations should be conducted at pre-employment; prior to assignment to a work area that has high volumes of noise; annually, if the employee is still working in a noisy area; when being reassigned to another area after being expose to noise and lastly, at the termination of employment (OSHA, 2002). The two most important audiograms in the hearing conservation programme are the baseline audiogram and the annual audiograms (OSHA, 2002). Furthermore, audiometric evaluations serve as an opportunity to educate and train employees about the importance of preserving their hearing as employees who understand the objectives of a HCP are more likely to protect their hearing (OSHA, 2002). Employers are mandated to keep audiometric evaluation results for as long as the worker is employed. Therefore, this study highlights the need to conduct ongoing baseline and annual audiograms.

Over and above the aforementioned challenge identified in the current review of the fact that no single study focused on comprehensive HCP (inclusive of all pillars) in the management of ONIHL, there were also shortcoming with the methods used to collect data. Of the studies that utilized interviews and questionnaires and archival record reviews, the highest number of

participants included was 200. These small sample sizes negatively impacted the ability of the findings to be generalizable. Therefore, current studies yielded findings where concluding that the strategy used to minimize noise and its impact became difficult.

4.7 Conclusion

Evidence-based interventions based on best practice are critical in any health and safety programme. The fact that HCPs are complex interventions that include a variety of factors and a range of stakeholders, with diverse influencing factors; current findings are concerning. Firstly, the fact that there is such limited research conducted on HCPs in Africa is a significant drawback to the collation of contextually relevant evidence that can be used to implement effective HCPs; and the fact that most of this evidence was from South Africa alone is an even bigger concern. Secondly, the piecemeal fashion of studies that have been conducted; where individual pillars instead of comprehensive holistic HCP analysis is done also impacts negatively on identifying gaps and/or weak links in any HCP. Thirdly, the fact that only four of the pillars have been investigated over the review period limits the amount of evidence available to the mines as well as evidence for future planning. Lastly, the fact that the studies reviewed generally included small sample sizes means that findings from these studies are not easily generalizable to the African mines generally. Current findings, which provide an overview of studies in HCP and ONIHL in Africa, add to the evidence base, which can be consulted in planning future studies, in formulating policies around hearing conservation, and in planning and implementation of HCPs. These findings should be interpreted taking careful cognizance of the design and methodology adopted in the review.

CHAPTER 5. MANAGEMENT OF OCCUPATIONAL NOISE INDUCED HEARING LOSS IN THE SOUTH AFRICAN MINING SECTOR: A VIEW FROM THE TOP



Hearing loss is a terrible thing because it cannot be repaired. *(Pete Townshend, n.d.)*

Management of Occupational Noise Induced Hearing Loss in the South African Mining Sector: A View from the Top

5.1 Abstract

Exploring the views of various stakeholders, who are potentially policymakers on occupational noise and its management, is crucial as these engagements may assist in the formulation, implementation, monitoring and evaluation of policies on excessive noise in the workplace. Therefore, adopting a qualitative approach, sixteen stakeholders were recruited through snowball sampling. Data were collected through in-depth interviews and analysed using inductive thematic analysis allowing themes to emerge.

Barriers and facilitators in the implementation of hearing conservation programmes (HCPs) can be addressed through careful, comprehensive and systematic collaborative engagement of all stakeholders in the mining industry to ensure interventions aimed at eliminating excessive noise in the mining industry are achievable. Findings also highlighted the importance of viewing and treating HCPs as complex interventions to improve occupational healthcare among individuals exposed to excessive noise in the workplace.

Key-words: Stakeholders, mine health and safety milestones, occupational noise, hearing conservation programmes, complex interventions

5.2 Introduction

Occupational noise-induced hearing loss (ONIHL) is an occupational disease defined as a permanent sensorineural hearing loss caused by exposure to excessive levels of noise during the performance of one's occupation (Lie, Skogstad, Johnsen, Engdahl, & Tambs, 2015; Nelson, Nelson, Concha-Barrientos, & Fingerhut, 2005; Thorne, 2006). It has been dubbed as a number one work-related disability, and the second most common form of acquired hearing loss after presbycutic hearing loss (Ritzel & McCrary-Quarles, 2008). Most recently, ONIHL has been characterised as an important public health priority because populations are now living longer. Thus, growth in the development of industries around the world is adding to the global burden of disease (Nandi & Dhatrak, 2008). Yongbing and Martin (2013) describe noise induced hearing loss as a potentially costly public health issue, especially in developing countries.

South Africa is a developing country and its mining industry is one of several influential energies behind the country's economic growth. Currently, mining in South Africa is reportedly a significant contributor to the economy in that it contributes an average of 20% to South Africa's GDP, while boasting a total annual income of nearly R550 billion. It is one of the country's biggest employers with more than a million employees in mining-related employment. These are mostly black males and therefore the mining industry is regarded the largest contributor by value to black economic empowerment in the South African economy (Worldwide Recruitment Solutions, 2014). It is for this reason ONIHL is considered one of the contributors to the country's economy and public health concerns.

In South Africa, evidence from some mines reveals the majority of the mines' workforce is exposed to unsafe noise levels exceeding 85 decibels A-weighted (dBA) in intensity. This is endured over an eight (8) hour working shift – a 40 hour per week weighted average (TWA)

(Hermanus, 2007). In fact, Hermanus (2007) reports 11% of workers are exposed to noise levels far exceeding the 85 dBA limit. Therefore, increasing the chance of ONIHL occurrence within the South African mining population. This is particularly true when one considers the South African mining industry is frequently criticised for its poor health and safety records and high numbers of fatalities. However, more recent reports indicate these conditions are improving.

In 1994, the Leon Commission of Enquiry into Health and Safety in the mining sector was appointed and mandated to make recommendations regarding health and safety concerns in the mining industry (Stanton, 2003). The Commission made recommendations under Section 4.17.1 - 14.17.4 of the report, to make provisions for the control of noise and the introduction of a hearing conservation programme where workers are exposed to levels in excess of 85 dB (A). It also made a provision for the use of personal protective equipment in the mines (Stanton, 2003). The obvious goal of these provisions was to improve the monitoring of standards and practices, to ensure firm adherence to medical surveillance and to enhance control of health risks. (Hermanus, 2007; Stanton, 2003).

In 2003, to address identified concerns regarding excessive noise in mines, the South African Mine Health and Safety Council (MHSC), comprising of State, Labour and Employer representatives reached an agreement with the mining industry pertaining to the introduction of two milestones. In the mining industry, these were dubbed the MHSC 2003 ONIHL milestones (Phillip, Heyns, & Nelson, 2007; Strauss, Swanepoel, Becker, Eloff, & Hall, 2014).

The first milestone aimed to eliminate hearing deterioration greater than 10% in individuals who are exposed to excessive occupational noise by December 2008. The second milestone aimed to minimise the total noise emitted by any kind of equipment to less than 110 dBA at any point in

the workplace by December 2013(Phillip et al., 2007; Strauss et al., 2014). These milestones were crafted to promote hearing conservation programmes (HCP) in the mining sector. Current milestones still focus on the significant threshold shift (i.e. significant disability), rather than prevention. Therefore, they are still not strict enough.

Studies investigating HCPs locally found a heavy focus on the use of personal hearing protection devices as a strategy to deal with ONIHL (Bruce, 2007; Bruce & Wood, 2003; Hong, Kerr, Poling, & Dhar, 2013; Moroe, Khoza-Shangase, Kanji, & Ntlhakana, 2018; Suter, 2012). Additionally, the industry downplays the importance of engineering controls in the form of buying quiet, as well as education which can be achieved through conducting educational awareness campaigns on the impact of ONIHL. This lack of implementation of comprehensive HCPs illustrates a lack of adherence to official guidelines. These include recommendations from the Department of Mineral Resources. DMR guidelines recommend the use of personal protection devices as a temporary and last resort if engineering and administrative measures fail (DME, 2003).

In 2013, evaluation of the 2003 milestones indicated they had not been achieved (Edwards, Dekker, Franz, van Dyk, & Banyini, 2011; Edwards & Kritzinger, 2012; J.J. Dekker, A.L. Edwards, R.M. Franz, T. van Dyk, & A. Banyini, 2011). Consequently, these milestones were then revised to recreate the 2014 MHSC milestones. The first milestone was aimed at Quietening of Equipment, and stated that by December 2024, the total operational or process noise emitted by any equipment must not exceed a milestone sound pressure level of 107 dB(A).

The second milestone was aimed at the individual, mandating by December 2016, no employee's Standard Threshold Shift (STS) should exceed 25 dB from the baseline when averaged

at 2000, 3000 and 4000 Hz in one or both ears. These ever-moving targets highlight the importance of exploring challenges and barriers towards achieving these milestones; hence, the current study.

5.3 Material and methods

Methods followed in this study have been described previously (Moroe, 2018).

5.3.1 Objective

The current study is part of a larger study titled: Occupational Noise Induced Hearing Loss in South African Mines: From Policy Formulation to Implementation and Monitoring. The objective of this portion of the study was to explore the views of various stakeholders on the formulation, implementation, monitoring and evaluation of the Mine Health and Safety Councils' 2003 ONIHL milestones.

5.3.2 Research methods

A qualitative research strategy was undertaken to understand and illuminate the views of stakeholders on the MHSC 2003 ONIHL milestones. A qualitative approach was chosen for its naturalistic approach in seeking to understand a phenomenon in context-specific settings, without researcher influence, thereby eliminating manipulation. This approach also allows the phenomena of interest to unfold naturally (Golafshani, 2003; Patton, 2005). Furthermore, qualitative research is concerned with illuminating, understanding and exploring the phenomena within its context (Hoepfl, 1997), which is the aim of the current study.

5.3.3 Sampling Strategy

A non-probability purposive sampling strategy was utilised to recruit possible participants who met the inclusion criteria (Rosnow & Rosenthal, 1996). Participants were identified from websites of companies affiliated with the South African mining industry. Participants were contacted via emails and telephonically and thereafter requested to participate in this study. Moreover, they were further requested to suggest other participants who could be invited to participate in the study.

5.3.4 Inclusion criteria

- All participants were required to be employed or contracted to the mines for six months or more
- Participants had to be aware of and active in HCPs implemented in the mines.

5.3.5 Sample Size

A total sample of sixteen participants was obtained and interviewed for the study (Table 1). Three participants were excluded as they had less than six months' experience being involved in management of ONIHL in the mining sector. Participants compromised six representatives from the state, labour and employer, seven audiologists and two ventilation and occupational health engineers, plus one occupational hygienist.

5-1: Table 1- List of participants and their occupational positions

Participant	Position	Group
1	Labour	MHSC
2	Employer	MHSC
3	State	MHSC
4	Employer	MHSC
5	Employer	MHSC
6	Employer	MHSC
7.	Senior Ventilation and Occupational Health Engineer	Occupational officer
8.	Ventilation and Occupational Health Engineer	Occupational officer
9.	Occupational hygienist assistant	Occupational officer
10	Audiologist – Private company affiliated to a mine	Audiologist
11	Audiologist – private practice affiliated to a mine	Audiologist
12	Audiologist – employed at a mine	Audiologist
13	Audiologist – private contractor at a mine	Audiologist
14	Audiologist - private practice affiliated to a mine	Audiologist
15	Audiologist – Private company affiliated to a mine	Audiologist
16	Audiologist – Private contractor at a mine	Audiologist

5.3.6 Data collection

In-depth qualitative interviews were conducted with participants. Interview questions were formulated by the researcher based on the literature review and the document analysis of regulations, policies Acts on the management of ONIHL in the mining industry. The interview structure followed the recommendations by where the interviewer possesses a plan of inquiry as

well as a set of questions (Rubin & Babbie, 2005). Furthermore, Kerlinger and Lee (2000) also recommends similar questions be grouped together in order for cohesion and order.

Interviews were conducted in a conversational manner and the questions were not asked in a specific order. Interviews had a duration of thirty to forty-five minutes to complete. Interviews were conducted in English, as this was the language of choice for all the participants. Broadly, the questions focused on the participants' occupational positions; their role and views on the formulation and implementation of the 2003 milestones/HCPs. As well, their opinions regarding factors affecting HCPs were discussed.

5.3.7 Ethical considerations

All procedures contributing to this work complied with the relevant standards of the national and institutional guidelines on human subject for research purposes. Therefore, this study adhered to the Helsinki Declaration of 1975 as revised in 2008 (World Medical Association, 2008). Consequently, prior to commencing with the study, approval was obtained from the University's Human Research Ethics committee (Medical) (Protocol number: M160264) and from a platinum mine in one of the provinces in South Africa. Furthermore, ethical aspects such as confidentiality, right to withdraw from the study were discussed with the participants. Anonymity, however, was not guaranteed as snowball sampling was utilised in this study. Participants were made aware all information provided to the researcher would be kept confidential.

5.3.8 Data collection procedure:

Initially, possible participants were contacted telephonically or via email to request their participation in the current study. In line with purposive snowball sampling, participants were only contacted when the referring person obtained permission from possible participants to forward their contact details to the researcher. The researcher contacted the potential participants asking if they were still willing to participate. Participants were furnished with relevant information such as the information letter and consent forms.

On the day of the interview, upon arrival at the set venue, the researcher introduced herself and again highlighted the aim of the interview including ethical considerations. Participants were again provided with hard copies of the information letter and consent forms. Furthermore, they were given an opportunity to read and to ask questions if they felt it necessary. Participants were required to sign consent forms to indicate they were voluntarily agreeing to participate. With permission from all participants, interviews were audio-recorded for purposes of later analysis as well as to increase the accuracy of data collected. This allowed the researcher to be fully attentive to the participants instead of handwriting verbatim transcripts during the interviews.

For telephonic interviews, participants were emailed the information and consent letters. They were requested to return the consent form prior undergoing the interview. These interviews were conducted via teleconferencing in order to audio-record them. Overall, eight participants opted for telephonic interviews due to time constraints.

5.3.9 Data analysis

Inductive thematic analysis was used to scrutinise the data as it allowed for the coding of data without fitting it into a pre-existing coding frame. This method also prevented the influence of the researcher's analytic preconceptions and thereby allowing for themes to emerge from the data (Braun & Clark, 2006). Themes emerging from this data were analysed using the steps recommended Braun and Clark (2006) viz. familiarisation with the data, generate initial codes, search for themes, review themes, define themes, and write-up. A sample of representative verbatim quotations were then used in the write-up of the study to support current findings.

5.4 Trustworthiness

Reflexivity and bracketing were applied to guard against any bias from the researcher. A peer reviewer served as a mirror and assisted in reflecting on the researcher's responses to the interviews. Also, the current authors made use of the "community of practice" to share the process and findings of the study with a group of colleagues familiar with ONIHL and policies governing noise management in the mines (Rossman & Rallis, 2003, p. 69). Furthermore, after transcribing the interviews, the researcher conducted member or participant checks to "learn from the interviewee how well the researcher's interpretations reflect the interviewee's meaning" (Morrow, 2005, p. 254). Thereafter, following the transcription of interviews, the researcher contacted some participants for more clarification when it was required.

5.5 **Results and discussion:**

Inductive thematic analysis used to analyse results revealed the following themes: crisis management, some are more equal than others, cost of an individual's hearing, knowledge is power and show and tell.

These themes are discussed and supported by quotations below.

Theme 1: ***A crisis management***

All participants expressed frustration with the lack of direction in terms of having clearly defined action plans to guide the process.

P5 shared the following:

> "*…but when I joined in 2007, there were quite a number of gaps then. I would say I was able to have influence; therefore, the processes continued. In 2008 we were able to come up with the summit action plans… because in 2003 they crafted the milestones; but there were no action plans as to how we were going to achieve the programmes that were put in place to ensure that the milestones were achieved".*

P 10 revealed…

> '*The approach has always been problem-finding, not preventative. The way they (milestones) were presented or formulated, they were really aimed at managing, maybe to an extent, but not at eliminating (the problem)."*

P 7 described the 2003 ONIHL milestones as

> *"…a crisis management! The mining industry was not ready, hence the failure of the initial milestones. The process followed when the milestones were formulated was simply wrong.*

The mines were not ready in terms of cost and infrastructure, and the mines were not supported."

Over and above the lack of concrete action plans, participants also voiced unhappiness with a lack of collaboration and accountability from all stakeholders.

P2 lamented the lack of buy-in:

"*You know what? I guess the process was a bit (haphazard)… because from the beginning there was no buy-in from the stakeholders"*

P 4 added…

"There was not enough collaboration. It was not enough. It's actually unilateral implementation and decision making. If it (the decision or suggestion) comes from Safety, then Health does not get involved. Employees are not involved in the development of that conservation programme. Line management is not involved. They don't even understand what they need to do".

P 6 elaborated

"…Poor collaboration. I mean, you need all stakeholders on board. You need leadership commitment because they are the ones who will provide funding and make sure that initiatives are carried through, are monitored, and are… just basically, holding each other accountable. So (leadership) they need to be at the forefront, understand, and commit to making sure that this is not just a compliance issue. It has to do with people's health and we want to conserve health."

According to Byrne (2005) the first step the mines should consider before implementing a programme is addressing administrative issues; where company regulations or policies are clarified, and where individuals' responsibilities and roles are identified and enforced. Furthermore, the National Center for Injury Prevention and Control (2011) suggests the efficacy or success of any policy or regulation heavily relies upon the sound knowledge and involvement of the policy makers and stakeholders involved from conception to implementation, monitoring and evaluation.

Findings of this study indicated none of the stakeholders interviewed in this study were involved in the crafting of the 2003 milestones. Perhaps, this may explain the lack of collaboration and the 'not buying-in' of all stakeholders in HCPs and the lack of having clearly defined action plans. The results above highlight the complexity in the formulation and implementation of HCPs, in that, HCPs are complex interventions. They require having clearly defined goals and theories and are dependent on the involvement and sound knowledge of all stakeholders involved. If there are no defined goals or action plans as well as complete support from stakeholders, the success of the programme or project will be compromised.

Harris, Croot, Thompson, and Springett (2016) recommend stakeholders should preferably be involved from inception to the completion of the process. However, due to complexity and long timelines from formulation to implementation, monitoring and evaluation, stakeholders may be co-opted as and when their skills are needed.

Theme 2: Some are more equal than others

Audiologists, who, theoretically are involved in the management of occupational noise due to their training and their scope of practice, lamented their exclusion in the formulation of the 2003 MHSC milestones. However, they are expected to execute certain functions without their involvement in discussions regarding their role and expertise in the management of ONIHL in occupational settings.

P 12 stated:

> "*That's what has always been a concern, really. People are making decisions about our involvement in certain things, but are not involving us in the decision-making processes; and that has not really stood well with me*".

P16 alluded to financial costs as one possible reason for excluding audiologists from actively participating and influencing the direction of HCPs in the mining sector.

> *"So that's also something that shocked me recently, because now you will find that people, because of costs, are taking an admin person (administrative support staff) and sending that person for five days training; and the institution giving the certificate. The person is qualifying as an audiometrists, they are just registering at SASOHN*[i]*. SASOHN is just keeping the register. They are not seeing if the person is fit to do the job or qualified to do the job…just as long as they have the certificate. They will put their name on the register and that person performs the testing. Someone who cannot identify pathology, cannot look into someone's ears, cannot really interpret the graph or the depth… and that's how it's done. To be honest with you, it's a big challenge; and this needs to be challenged. There are a number of questions with the HCP".*

P 13 mentioned specific duties directly linked to audiologists' role in the management of ONIHL

"If you go to XXX (name of company removed), people who deal with the claims (occupational noise induced hearing loss compensation claims) do not have an audiologist on their staff; but they are assessing thousands of claims. I think we have quite valuable input to give, but we are absolutely not given an opportunity to do that, you know…"

Interestingly, when non-audiologist participants were asked about their opinions of the involvement of audiologists in the decision-making process, their responses varied from acknowledging the importance of including audiologists, to employing their services on a need-to-basis or not needing them at all. Five participants conceded audiologists should be included in the management of noise while the remaining four participants felt audiologists are not all that important in the management of noise. For instance, P 2 stated:

"*I think there is a role for audiologists to play, I guess. Firstly, there aren't many, you know, audiologists in my understanding; but ehhh… Secondly, especially at MHSC, they can always bring in specialists. So, there is a role for specialised skills. For instance, audiologists are part of the team, you know, at [the] company level, but not at [the] decision-making level."*

P 3 explained:

Well you see, the audiology part of it is not really taken care of within the mines themselves. The mines employ qualified hygienists, qualified medical doctors; but when it comes to audiologists, I do not know what happens. They even opt for small, cheap courses on audiometry for three days, and want to use those who attend these courses as qualified audiologists."

P5 summarised the role of audiologists in this manner:

> *"So in a nutshell, in terms of decision making, I think that what I'm saying is that audiologists are not in the structures that could influence some of the decisions; but in terms of operational level, audiologists oversee the audiometrics. So they are hands-on in terms of overseeing how we assess, how we manage, how we counsel our people."*

P 2 elaborated on the role of audiologist in the formation of 2014 milestones:

> *"For instance, when we were working towards the 2014 milestones, the new milestones, we got in an audiologist, you know, because we were debating, for instance, should we use the PLH (Percentage Loss of Hearing) shift or should we use the STS (Standard Threshold Shift) as a way of early detection of noise (induced hearing loss). So, an audiologist from an academic institution was invited, and she went through the pros and cons and in the end, we all agreed as the industry that we will shift from PHL shift to STS. So that's why the new milestones are based on STS shift".*

Findings indicate that although audiologists were not initially included in the formation of the 2003 NIHL, they were consulted in the revision of these milestones. In fact, it was the audiologist's input that shaped the new milestones from PLH to STS monitoring. Management of ONIHL is at the heart of the scope of practice for audiologists.

According to the American Academy of Audiology (1997) audiologists are the principal advocates for and supervision of HCP. Audiologists design, implement, and coordinate occupational and community hearing loss prevention programs. As cited in the American Academy of Audiologist Position Statement (2003), the role of audiologists includes: identification and amelioration of noise-hazardous conditions, identification of hearing loss,

recommendation and counselling for use of hearing protection, employee education, and training and supervision of non-audiologists performing monitoring audiometry in the occupational setting (American Academy of Audiology, 1997).

Furthermore, the success in reducing or even eliminating ONIHL in the workplace depends on the interaction of stakeholders who are part of the HCP team (audiology, occupational medicine, otolaryngology, occupational health nursing, occupational hygiene, engineering and safety) (American Speech-Language-Hearing Association, 2004). Audiologists can bring relevant knowledge and skills about hearing and communication in the workplace.

Audiologists have a strong background in aspects such as audiometric monitoring and interpretation of audiograms, equipment calibration, noise exposure assessment, hearing protection devices, and education for workers, and management. Other HCP team members can offer appropriate guidance and leadership in the development and continuation of HCPs implementation (American Speech-Language-Hearing Association, 2004).

Therefore, audiologists play an important role informing policy makers about the effects of hearing loss, not just the immediate effects, but also long-term effects of exposure to noise as well as the quality of life of the people exposed to noise. Findings of the current study highlighted the importance of the involvement of audiologists in the decision-making process when critical decisions regarding ONIHL and its management are discussed.

Although the participants were not clear or in agreement with regard to the involvement of audiologists in the management level, participants' assertions attest to the need for the involvement of audiologists in the formation of the policies and milestones in ONIHL. Moroe and Khoza-Shangase (2018) conducted a study on the role of audiologists in the management of occupational

noise in the mining industry. Findings revealed that occupational audiologists are minimally and peripherally involved in developing and executing HCPs. These authors speculated that lack of progress in eliminating ONIHL in the mining sector may be attributed to limited involvement and engagement of audiologists in the formulation, implementation and evaluation of HCPs.

There is therefore a need for audiologists to advocate for their role in the management of ONIHL in the occupational settings. Also, audiologists need to ensure that their training adequately prepares them for effective participation and engagement at decision-making level as the management of ONIHL is at the heart of the scope of practice for audiologists.

Theme 3: Cost of an individual's hearing

Most participants indicated regarding management of ONIHL, investing in engineering controls, in the form of "buying quiet" will assist in reducing and ultimately eliminating new cases of ONIHL in the mines.

P9 declared:

> "*On top of the list is "buying quiet".*

P 1 recalled:

> "*In 2014, we lowered it (noise emitted by equipment) to 107 (from 110dB) in terms of decibels. Uhm, however, we went beyond that. That is, in terms of quietening equipment. We still maintained the quietening of equipment as a priority because that's what the hierarchy of control requires."*

P 14 elaborated further:

> *"And then also at site level you need to know our company, not just our company, most of the big companies are doing the buy-quiet programmes. They are not buying equipment that is emitting more than 107dB or whatever your companies' requirement may be. So, we have that in place. And, also, on [the] site level, we are looking at muffling equipment. You know, at one of the plants they are putting, for instance, this conveyer belt. They're putting it in strategic places to help eliminate noise… where the crushers are and all that. So there is a lot of that actively happening, so you know… modifying the equipment, buying different equipment, you know, changing to more quiet machines".*

While participants reported a shift toward "buying quiet", four participants, particularly the employer representatives, also cited concerns regarding the cost of buying quieter equipment. However, there were responses to this argument.

P2 shared the following:

> "*I think if people stop at just looking at the money, the cost, you know, and say what is the cost to human beings when they lose their hearing. Then you can start levelling off and saying 'are you prepared to have 100s of people losing their hearing because you don't want to buy something that is slightly more expensive?'"*

Additionally, P1 lamented:

> "*We cannot talk health and safety… and talk costs. What is the cost of an individual's hearing?"*

These results indicate a strong commitment by the mining industry to the elimination of ONIHL. As well, their acknowledgement of how they value the wellbeing of their employees is to be commended. Hence, there is a commitment to investing in engineering controls by "buying quiet". Engineering controls are the first line of defence against exposure to loud noise, and if implemented correctly, there may be no need for other controls such as the use of personal hearing protection devices (Byrne, 2005).

Furthermore, costs related to hearing monitoring in the form of regular hearing tests; as well as expenses related to compensation may also be eradicated completely. This would be over and above the elimination of disability suffered by employees. This is supported by Bruce (2007) who asserts implementation of engineering controls has benefits which include "permanence, effectiveness with or without worker/supervision compliance, less absenteeism, easier communication, lower worker compensation outlays, and reduced legal expenditures".

These benefits should be a strong incentive for the mines to invest in "buying quiet". However, there are concerns that "buying quiet" is arduous and costly (Bruce, 2007). Participants in the current study also shared the same sentiments with regard to 'buying quiet' being very expensive. Adopting a position where 'buying-quiet' is structured as a long-term investment, perhaps, the benefits may far outweigh the perceived cost.

Based on current participants' responses, it is clear the South African mining industry is committed to prioritising and investing in 'buying-quiet'. The fact all participants felt strongly about it indicates the mining industry's united stand on conserving their employees' hearing. This is an encouraging step towards eliminating ONIHL in the mines.

Theme 4: Knowledge is power.

Unanimously, all participants agreed the focus on awareness campaigns has changed the mind-set of employers and employees. P 5 expressed the following:

> *"…the change in the culture in terms of education and awareness is exciting. The Occupational Health Hub Centre has brought a new focus. We came up with different clippers… more customised noise clippers*[ii] *which also made a huge difference, and through that, there was more engagement with the employee so that at least there is a one-on -one counselling. As a result, we developed a more detailed counselling form, you know, that talks to the person on what they understand, what they are doing, how it's going to benefit them going forward*";

P 10 stated:

> "*We conduct campaigns from time to time. Campaigns that's when we will meet the workers, we collaborate with stakeholders… various, depending on the campaign drive. Then we will raise awareness. That's where we hammer on the importance of use of appropriate PPEs. Not just PPE but appropriate. Yes, that's when we will sort of hammer down to the ordinary member the importance..."*

While P4 said:

"We also have campaigns.

> *We've collaborated with Hygiene (practitioners) on medical campaigns. If we have a TB day, you invite the noise clipper guys for on-going awareness. When we have your HIV*

day, your health days, we rope in hygiene as well. So, it's on-going via medical surveillance. It's on-going during campaigns".

These findings suggest the stakeholders may have had difficulties with collaboration in regard to meeting the 2003 milestones. However, the mining companies represented seemed to have made major strides in developing education campaigns in raising awareness on the effects of noise on the exposed individual's wellbeing.

What emerges from these results is, where the mines are concerned, a concerted effort in engaging all key stakeholders in raising awareness on the importance of conserving hearing. Furthermore, current results highlight the observable difference and change in attitude among employers and employees. Perhaps, this success the mining industry is experiencing in raising awareness may be attributed to engagement of all stakeholders in the decision-making process on programmes speaking to all the stakeholders' needs and commitment in terms of combatting ONIHL in the mines (Amedofu, 2007).

According to the National Center for Injury Prevention and Control (2011) without the stakeholders' support, the process and implementation of any programme may be ignored, criticised, resisted or even sabotaged. Furthermore, for campaigns to be effective, proper planning with clear objectives and desired outcomes is necessary to enhance the success of these programmes (U.S. Department of Health and Human Services, 2011).

Most studies on the management of ONIHL have ignored the importance of including employees as stakeholders. HCPs are implemented to protect employees who are exposed to hazardous noise in the workplace. However, if employees are not aware of the importance of safe-guarding their hearing and the severe consequences which extend beyond the physical disability,

they are not likely to be active participants in protecting their own hearing. Therefore, there is a need to include employees as stakeholders in the management of noise. Obviously, this is because they are the individuals affected by excessive exposure to noise. Including them in the noise management process will empower and make them active participants in minimising their exposure.

Theme 5: Show and tell

Another theme emerging from the results was the use of "Leading Practice" as a way of encouraging all stakeholders to develop initiatives to assist in the elimination of ONIHL in the mining sector. This was a response to the realisation certain mines or companies were developing excellent and effective initiatives. However, they were not sharing their advancements with the other mines.

P 14 expresses this well:

> "*We are working with the engineers, because I know there was a project through MOSH*[iii]*. MOSH… what they promote is, it's not best practice, through the Chamber (of Mines). The Chamber has a section that they call MOSH, and at that Unit, they look at what works in one of the mines through leading practice… Meaning that they look at each other; their operations and see what they are doing that helps and then it can be adopted into practice across. This is where someone takes innovative, tries out other things that can be better than what is being done. Once it has been proven to be effective/successful, it can be adopted as leading practice for the industry*".

P 12 further elaborated:

> "*A lot of what we did as the employer on noise, and also on transport and machinery, is through the Learning Hub. It's the Mining Occupational Safety and Health Learning Hub. So… it's a whole unit that was established by the Chamber. It was established in 2008 to advocate for or assist companies to adopt leading practises in two areas – dust and noise. The rational was that a lot of companies have individual practises. You know… they have good work that they are doing but it doesn't necessarily get disseminated throughout the industry. Of course, people sometimes… they sort of… are living in a silo environment and they do not learn from each other, so it was part of companies learning from each [other]."*

P 1 supports this here:

> *"That's our basis. But the reality is that you have small scale mining and you've got fully established like your XXX (name removed) and you can't put them… so we are busy developing a guideline for small scale where they can have considerations. But the bottom line is that in certain aspects, once we have identified the leading practice it's what we will use to roll out whether you are small scale or not".*

The findings above indicate the value for the mining industry to learn from each other and to promote engagement from various departments and stakeholders. This promotes a focused goal as opposed to working in silos. According to Malatji (2015), leading practice is concerned with identifying, implementing and disseminating best innovations in health and safety through "encouraging the mining industry to learn from the pockets of excellence existing in the mining industry".

Working as a group, and not in silos fosters cross-fertilisation of ideas as different mines might share strategies viewed as effective in their mines. Arguably, some ideas may not work for all mines, for instance small scale versus large-scale mining. However, cross-fertilization allows for transparent and meaningful exchange of knowledge to achieve meaningful decisions for improving occupational health and safety in the workplace.

5.6 **Conclusion**

Current findings regarding stakeholders' views on the management of ONIHL in the South African Mining Sector contribute to the evidence-base in the developing country context where ONIHL remains a serious occupational health condition. This also includes the importance of quality of life as well as financial implications.

The current study revealed factors contributing to the failure and success of the South African mining industry in meeting milestones related to HCPs. Additionally, it has also highlighted factors which, if applied systematically, may contribute to the success of hearing conservation targets. These findings raise important implications for the South African mining industry in terms of areas needing attention to augment successful and collaborative implementation of all HCPs initiatives.

The stakeholders have highlighted the importance of ensuring collaborative work. They indicate a need for less individualised programmes where there is limited sharing of leading practice within the industry. Therefore, comprehensive, systematic and possibly industry strategy around noise, noise exposure, and the effects of noise on hearing are essential to establish what is effective and then apply this throughout.

Based on this study, the main contributing factor for not meeting proposed targets was the Council's failure to establish and define the summit action plans prior to implementing the milestones. Secondly, the revealed lack of collaboration by all stakeholders in the mining sector, as well as the exclusion of audiologists in the formulation of the 2003 milestones, illustrate why success in achieving the milestones remains elusive.

The need to correct the current measures identified are aimed at ensuring the success of hearing conservation targets are significant findings from the current study. Now they require careful deliberation by the South African mining industry. The adoption and actual implementation of 'buying-quiet' equipment; regardless of the immediate costs is an important first step. As well, the adoption of leading practice; development of effective awareness campaigns to combat ONIHL in the mining industry are powerful possible strategies which may have a significant impact in elimination of ONIHL.

Current findings indicate the requirement of continued effort for identifying and removing barriers towards elimination of ONIHL as a health challenge within the mining industry. As well, there is need for careful, comprehensive and systematic collaborative engagement of all the stakeholders in the mining industry to ensure targets set are achieved.

5.7 **Implications**

The current study revealed some difficulties faced by the mining industry in achieving the 2003 NIHL milestones. Failure to meet those milestones attest to the complex nature of HCPs in the management of ONIHL in the mines. It is therefore recommended the mining industry should view HCPs as complex programmes requiring complex interventions.

Complex interventions are built from multiple interacting components. These may include behaviours, behaviour parameters and methods of organising those behaviours. Additionally, they may have an effect at the individual level, organisational level, or population level. These factors may act both independently and interdependently (Datta & Petticrew, 2013; Medical Research Council, 2000; Moore et al., 2015).

To date, complex interventions have not been conducted in the field of occupational audiology more specifically, HCPs. HCPs in their own right are complex interventions built from interacting components (pillars) and are influenced by interactions at the individual, organisational and community levels (Moroe, 2018). HCPs are implemented to reduce exposure to excessive noise in the workplace, with the aim of improving occupational health care. Therefore, there is a need for the mining industry to view HCPs as complex interventions, aimed at improving the quality of life and health of workers potentially exposed to excessive noise in the workplace.

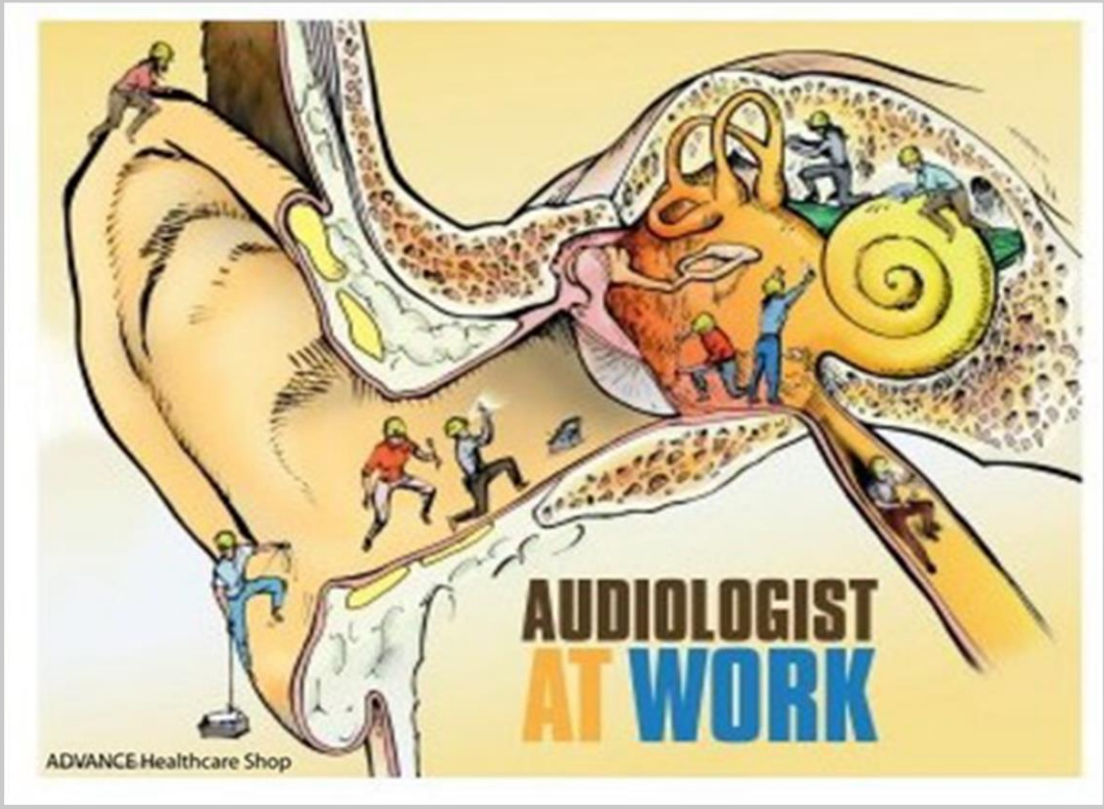
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Notes

[1] SASOHN – South African Society of Occupational Health Nursing Practitioners is a professional society committed to the development of the occupational health-nursing practitioner.
[b] Noise Clippers – Custom-made hearing protection devices implemented on a large scale in the South African mining industry(De Koker, Franz, Clark, & Mackay, 2003).
[c] MOSH – Mining Industry Occupational Safety and Health. The MOSH Leading Practice Adoption System is a process which identifies leading practices; selects and documents the best of them at the operational mine; and recognises possible aids and barriers to their adoption at other mines.(Malatji, 2015).

CHAPTER 6. MANAGEMENT OF OCCUPATIONAL NOISE INDUCED HEARING LOSS IN THE MINING SECTOR IN SOUTH AFRICA: WHERE ARE THE AUDIOLOGISTS?



Occupational health is an important strategy not only to ensure the health of workers, but also to contribute positively to productivity, quality of products, work motivation, job satisfaction and thereby to the overall quality of life of individuals and society *(Global Strategy on Occupational Health for All (1994)*

Management of Occupational Noise Induced Hearing Loss in the Mining Sector in South Africa: Where Are the Audiologists?

(Reprinted with permission, see appendix H)

6.1 Abstract

Objective: This study was conducted to explore the scope of practice for occupational audiologists in the mining industry and the audiologists' involvement in hearing conservation programmes in South African mines. Additionally, this study investigated the mining industry's role in the audiologists' involvement, and assessed the audiologists' levels of preparedness for working in occupational audiology. **Methods:** In-depth, qualitative telephone and face-to face interviews were conducted with seven occupational audiologists involved in the management of occupational, noise-induced hearing loss (ONIHL) in the South African mining sector. Snowball sampling was utilized to recruit possible participants for this study. Data were analysed using inductive thematic analysis. **Results:** The following themes were identified: scope-context misalignment, juniorization of the experts, audiologists are important... but for what? and limited training in occupational audiology. **Conclusions:** Our evidence highlights important gaps in HCPs in South Africa. The fact that the audiologists responsible for the management of ONIHL are only minimally and peripherally involved may play a significant role in the lack of progress reported in the management of ONIHL in the South African mining sector.

Key words: Audiologists, Conservation programmes, Hearing loss, Mining industry occupational noise, South Africa

6.2 **Background**

The audiology profession in South Africa (SA) is less than 100 years old, with only six of the country's 26 universities offering the training. The training of professional audiologists in SA has its origins at the University of the Witwatersrand (Swanepoel, 2006). The first programme was established in 1938 by Pierre de Villiers Pienaar, who established the Speech, Voice and Hearing Clinic in the University of the Witwatersrand (Aron, 1991; Swanepoel, 2006). Approximately 200 audiologists graduate each year. These audiologists have to work in government hospitals as part of a compulsory year of community service.

Post-community service, the majority of audiologists go into private practice, with a small number retaining government hospital jobs. This migration from government is influenced by a number of factors such as the structure and availability of government posts, which are accompanied by poor working conditions and resource constraints. Graduates register with the Health Professionals Council of South Africa (HPCSA) and are regulated by this council, with no involvement from South African Society of Occupational Health Nursing Practitioners (SASOHN). Consequently, their practice tends to neglect occupational health, specifically occupational noise induced hearing loss (ONIHL).

The prevalence of ONIHL remains one of the challenges in occupational health management in SA (Strauss et al., 2012). However, this challenge is not one of the South African Health Department's targeted priorities. Although the burden of disease that dictates health priorities includes conditions that are prevalent in the mining industry such as HIV/ AIDS and TB, not enough attention is paid to this part of health - occupational health. Therefore, assessment and management of ONIHL is a neglected public health issue. Currently, ONIHL falls under the purview of the Department of Labour as part of their occupational health and safety mandate, with

no oversight or accountability to the HPCSA or the Speech Language and Hearing Professions professional board, which is responsible for regulating the scope of practice of professionals dealing with ear and hearing function. The result of this fragmented structure is that there is no audiologist-led, structured, and well-coordinated hearing conservation program within the South African mining industry.

The American Academy of Audiology promotes audiologists as the principal advocates and supervisors of programs that manage the hearing health of people exposed to hazardous noise (American Academy of Audiology, 2003). Audiologists are tasked with "designing, implementing and coordinating occupational and community hearing loss prevention programmes. These roles require the identification and amelioration of noise hazards, the diagnosis of hearing loss, offering recommendations and counselling on the use of hearing protection, employee education, and training and supervising of non-audiologists performing monitoring audiometry in occupational settings" (American Academy of Audiology, 1997). However, the American Speech-Hearing-Language Association (ASHA) (1999) reports that few audiologists serve as consultants in the mining industry, and even fewer are involved in noise measurements, the training of occupational hearing conservationists, or hearing conservation programme audits and valuations.

In SA, there is a dearth of literature on the involvement of audiologists in the management of occupational exposure to hazardous noise in the workplace. Current evidence indicates that the South African mining industry is aware of the existence of audiologists and their role in the management of occupational exposure to excessive noise. According to section 43 of Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) audiologists are 'competent persons' in carrying out base line hearing level surveillance of people exposed to occupational noise in the workplace (Government Gazette, 2003). This document also states that occupational medical personnel and

medical practitioners specializing in otorhinolaryngology are ‘competent persons’ as long as they are registered with the HPCSA. Furthermore, audiometrists are also listed as ‘competent persons’: “A person with a qualification in audiometric techniques obtained from an institution registered with the South African Qualification Authority or any of its structures in terms of the South African Qualifications Authority Act, 1995 (Act No. 58 of 1995), and registered with the South African Society for Occupational Health Nursing” (SASOHN).

Dr. de W. Oosthuizen compiled the Guidelines for a Hearing Conservation Programme for the mining industry, detailing the role of occupational audiologists in the management of ONIHL (de W Oosthuizen, 2006). According to this document, this role is limited to conducting medical surveillance, thereby significantly reducing the role of occupational audiologists. The limited role of occupational audiologists is inconsistent and not in compliance with ASHA’s scope of practice as described above (American Speech-Language-Hearing Association, 2004). Therefore, this study aims to investigate the role of occupational audiologists in hearing conservation in the South African mining sector. This work is part of a larger study titled: Occupational Noise Induced Hearing Loss in South African Mines: From Policy Formulation to Implementation and Monitoring. The aim of this study was to explore the involvement and role of occupational audiologists in HCPs in the South African mining industry.

6.3 Methods

6.3.1 Study design

In-depth interviews were conducted for this qualitative study. Qualitative research uses a naturalistic approach in seeking to understand phenomena in context-specific settings without the influence of the researcher, eliminating manipulation of the phenomena of interest and allowing it

to unfold naturally (Golafshani, 2003; Patton, 2005). Furthermore, qualitative research seeks to illuminate, understand and explore a phenomena in its native context (Hoepfl, 1997). This study sought to illuminate and understand the involvement and role of audiologists in HCPs in the South African mining sector. Therefore, a qualitative approach was suitable for achieving this objective.

6.3.2 Sample size and sampling strategy

A sample size of seven occupational audiologists was obtained and interviewed for the study. The number of audiologists is relatively small; however, this in itself is a finding of this study, as it indicates the very limited involvement and employment of trained audiologists in the South African mining industry. When recruiting participants for this study, we discovered that the South African mining industry prefers to employ audiometrists over audiologists for occupational audiology work. Therefore, our small sample size validates the importance of the study, as it attests to the absence of occupational audiologists in the mining sector. Since this study consists of a small sample, its findings cannot be generalized to a larger population. However, this study is based on in-depth interviews, and according to Dworkin (2012), "in-depth interview work is not as concerned with making generalizations to a larger population of interest and does not tend to rely on hypothesis testing but rather is more inductive and emergent in its process."

Due to the small number of occupational audiologists in the South African mining industry, snowball sampling was used to recruit participants. Snowball sampling is a strategy where participants approach other people who meet the inclusion criteria defined by the researcher, and request that they also participate in the study (Penrod, Preston, Cain, & Starks, 2003). Snowball sampling was particularly important in this study as occupational audiologists are rare and difficult

to locate. Therefore, we took advantage of the social networks of identified participants to expand the set of potential participants, allowing a series of referrals to be made within a circle of acquaintances (Atkinson & Flint, 2001). However, snowball sampling is limited in that it does not recruit a random sample. Therefore, the sample used in this study may not be representative of a larger population (Sadler, Lee, Lim, & Fullerton, 2010). Participants were initially identified through a Google search for occupational audiologists in the mining sector. These audiologists were contacted via email and phone, and were requested to participate in the study and to suggest other study participants.

6.3.3 Inclusion criteria

Participants were required to be occupational audiologists who have worked in the mining industry for more than 6 months. Participants had to be aware of HCPs implemented in the mines. Additionally, participants had to be occupational audiologists either in private practice and contracted to the mines, or in private companies affiliated with the mines. The participants' profile is shown in Table 1.

6-1: Table 1- The participants' profile

Participant	Nature of affiliation to the mine	Years as occupational audiologist	Gender	Age
1	Private company affiliated with a mine	2.5	Male	36
2	Private practice affiliated with a mine	5	Female	32
3	Employed at a mine	8	Female	36
4	Private contractor at a mine	12	Female	43
5	Private practice affiliated with a mine	21	Female	47
6	Private contractor at a mine	37	Female	62
7	Private company affiliated with a mine	8	Female	40

6.3.4 In-depth Interviews:

Interview questions were formulated based on the available literature and analysis of regulatory documents, policies, and acts on the management of ONIHL in the mining industry. The interview structure followed the recommendations by Rubin and Babbie (2005), where the interviewer possesses a plan of inquiry as well as a set of questions. Furthermore, Kerlinger and Lee (2000) recommend that similar questions be grouped together in order to maintain cohesion and order.

Research questions focused on undergraduate training, occupational experience, workload, and involvement in HCPs. All of the interviews were conducted in English and were audio-recorded.

6.4 Ethical considerations

All procedures contributing to this work complied with the relevant national and institutional guidelines for research on human subjects, and adhered to the Helsinki Declaration of 1975 as revised in 2008 (World Medical Association, 2008). Furthermore, approval was obtained from the University of the Witwatersrand Human Research Ethics committee (Medical ;Protocol number M160264). Ethical issues such as confidentiality and the right to withdraw from the study were discussed with the participants. However, anonymity was not guaranteed due to the use of snowball sampling in this study. Participants were made aware that all information given to the researcher would be kept confidential.

6.5 Data analysis

Transcribed data was analysed through inductive thematic analysis. Inductive thematic analysis is a process of coding data "without trying to fit it into a pre-existing coding frame, or the researcher's analytic preconceptions. In this sense, this form of analysis is data-driven" (Braun & Clark, 2006). Themes that emerged from this data were analysed using the steps recommended by Braun and Clark (2006): viz familiarization with the data, generation of initial codes, searching for themes, reviewing themes, defining themes, and writing-up findings. Representative verbatim quotations are used to support the presented findings.

6.6 Trustworthiness

In order to address any biases or subjectivity in the handling and analysis of data, the authors acknowledge that "all research is subject to researcher bias" (Morrow, 2005). Therefore, a peer reviewer served as a mirror and assisted in reflecting responses to the interviews. Also, the authors made use of the "community of practice" (Rossman & Rallis, 2003) to share the process and findings with a group of colleagues who are experienced researchers and are familiar with the role of occupational audiologists. Furthermore, while transcribing the interviews, the researcher contacted participants when further clarification or additional information was required, and this information was in turn given by the participants.

6.7 Results and Discussion

The following themes were identified in the data: scope-context misalignment, juniorization of the experts, audiologists are important, but for what? , and limited training in occupational audiology. These themes are discussed below.

Theme 1: Scope-Context misalignment

Participants were asked to briefly discuss their typical caseload in order to ascertain their everyday involvement at the mines. Participants indicated that their caseload consisted of ear pathologies, hearing tests, and occasional hearing aid fitting.

> *"I get a very varied, interesting case load. I get a lot of middle ear pathology. Because we're mining in SA, the deepest in the world up to 5 kilometers, we get a lot of Eustachian*

tube problems and therefore a lot of middle ear pathology. You see a lot of ototoxicity, multidrug resistant TB, the influence of HIV. Very interesting and very varied caseloads. (P6)

Similarly, participant P2 has a varied caseload.

"Diagnostic hearing tests. I'm not so much involved with the counselling anymore because of the language barrier. I fit aids, not on a daily basis. Yes, we do see pathology, but not so much. We see a lot of cases but the main part of it is the hearing test."

Likewise, participant P3, who is an in-house audiologist, shared her caseload:

"Well, I'm situated at the occupational house centre, so we do the hearing medicals of the employees. So, I see all the people that have shifts in hearing when we're comparing to their baseline audiogram. So, I work out then if it seems noise induced hearing loss related or whether [there] are other factors contributing to the hearing loss. And then in cases where it's serious, I do referrals to ENT specialist[s] or to general practitioners. I also see the employees or patients that have pathology, wax, ear infections. I basically manage all the patients with regards to working out what the cause might be of the hearing loss." P3

The caseload mentioned by participants does not align with scope of practice of an occupational audiologist. The context in which occupational audiologists work dictates that they should be involved in developing, organizing, and administering HCPs in consultation with other stakeholders to effectively integrate contracted services where needed to supplement the employer's resources (Driscoll, Stewart, & Anderson, 2000; Royster & Royster, 1990)

Among other responsibilities, occupational audiologists are tasked with conducting programme audits and evaluations of effectiveness (Driscoll et al., 2000); maintaining familiarity with Workers' Compensation regulations and trends, as well as methods of claim evaluation(Dobie & Megerson, 2000); and the physical characteristics and methods of selecting HPDs appropriate for workplace demands and wearer needs(Berger, 2000). For a detailed scope of practice for occupational audiologists, readers are referred to the report by ASHA (American Speech-Language-Hearing Association, 2004).

The scope of practice of occupational audiologists extends beyond the scope of typical clinical audiology. Occupational audiologists should be in the forefront of advising companies about the auditory and non-auditory effects of noise on the health of the exposed individuals (Henderson & Hamernik, 1995), as well as the effects of noise on communication and job performance (Robinson & Casali, 2000). Currently, the services offered by occupational audiologists in the mines in SA are not aligned with the scope of practice defined by ASHA (American Speech-Language-Hearing Association, 2004).

Theme 2: Juniorizing the experts

Participants were questioned regarding their involvement in decision-making in formulating and implementing HCPs. Participants lamented that they are excluded from this process; however, they are expected to carry out certain tasks without consultation, which leads to the mining industry setting unrealistic expectations for audiologists.

"*...that's what has always been a concern really. People are making decisions about our involvement in certain things but are not involving us in the decision-making processes and that has not really sit well with me.*" (P5)

P4 stated:

"*Everyone is very... you know following the legislation around everything and its big mines we were involved with, but I was never, me as an audiologist, I was never involved or informed about the formulation or the implementation of the hearing conservation programme in the mine. However, I am expected to actively manage the workers who are exposed to excessive noise at the mines.*"

P6 lamented that audiologists' work is given to audiometrists with limited training:

"So that's also something that shocked me recently because now you will find people because of cost are taking an admin person and sending that person for 5-days training and the institution giving the certificate. The person is qualifying as an audiometrist, they are just registering at SASOHN. SASOHN is just keeping the register. They are not seeing if the person is fit to do the job or qualified to do the job as long as they have the certificate. They will put them on the register and that person is doing the testing. Someone who cannot identify pathology, cannot look into someone's ears, cannot really interpret the graph or the depth and that's how it's going. To be honest with you so it's a big challenge and this needs to be challenged. There is a lot of questions with the HCP." (P6)

These findings reveal a serious concern regarding mine management's practices when it comes to human resource protocols, as well as the expertise and scope of practice adherence. The fact that mines can assign an important health and safety role of ensuring minimisation and/or elimination

of ONIHL to a non-audiologist with no accredited training in the field raises questions about the political will of the mine's management to deal with ONIHL. It also highlights a gap for the advocacy role of audiology associations in the country, as well as the regulatory gap by the HPCSA. Arguably, audiometrists and occupational medical personnel may be 'competent persons' in conducting audiometric testing; however, the role of audiologists expands beyond medical surveillance. The role of audiologists begins at the conception and continues into the implementation, monitoring, and evaluation of HCPs. According to ASHA (American Speech-Language-Hearing Association, 2004, although a small percentage of audiologists specialize in occupational audiology, occupational audiologists play a leading role in the hearing conservation field. These professionals bring special knowledge about hearing and communication to the OHCP team, and participate in each program component to a greater or lesser extent depending on expertise and the particular employer's needs and resources (American Speech-Language-Hearing Association, 2004). Currently, the role and importance of occupational audiologists is not fully understood in SA, and consequently occupational audiologists are occupying positions below their training and scope of practise.

Theme 3: "Audiologists [are] important ...but for what?"

Participates were asked if they felt that mines' management were aware of the audiologists' role and if they received any support from management. Responses indicated that mine management has only a superficial understanding of the audiologist's role.

"I think they understand that it is very important that there must be an audiologist. But I don't think they always understand our work. Does that make sense? In my experience, I really never had direct contact with the management". P1

P5 shared the same sentiments:

"They do understand that there's someone, but not to the extent you'd want them to. Well they do understand even though sometimes they do confuse one, but it just depends on the level of management because I have been here for long enough. Not all the managers understand what you are about, but some they understand. But some will confuse the audiologist with an audiometrist."

P7 shared a different experience.

"Well, again I'm in an ideal setting. I do get good support from management. I direct any suggestion or complaints or problems to them and they will discuss it and support where possible. I've got quite a leeway. If I say something, they support it if it makes sense. But you know, I previously worked at a big mine hospital in a bigger set-up, and I didn't have the necessary support I felt I should have had because [of] cost and time. Employees need to go back to work, that's like the main focus. You can have settings where support isn't where it should be."

Poor understanding of the role of occupational audiologists is concerning, as poor support from management has implications not only for the mining industry, but for the individuals exposed to hazardous occupational noise and the states' resources (Berger, 2000; Dobie & Megerson, 2000). According to ASHA occupational audiologists are important in that they advise management on many operational aspects of HCPs such as management's responsibilities and liabilities under

federal, state, and local occupational health and safety regulations and Workers' Compensation statutes (American Speech-Language-Hearing Association, 2004). Furthermore, occupational audiologists can recommend the most successful and cost-effective means of implementing each component of the program, taking into account the advantages and disadvantages of developing in-house resources versus contracting with external service providers(Driscoll et al., 2000). Because occupational hearing conservationists such as audiometrists have a limited scope of practice, occupational audiologists are required to supervise OHCs (American Speech-Language-Hearing Association, 2004). In addition to the basic components of an effective HCP, occupational audiologists may be involved in forensic activities, such as serving as expert witnesses in hearing loss compensation claim cases and other forms of litigation (such as product liability) (American Speech-Language-Hearing Association, 2004). Currently in SA, the scope of practice for occupational audiologists does not reflect the roles described above, which may explain the poor understanding of the role of occupational audiologists in occupations exposed to excessive noise.

Theme 4: "Limited training in occupational audiology"

The participants were asked if their undergraduate training prepared them for their role as occupational audiologists. Only one participant, who trained in America, reported that they had received sufficient training. All participants who trained in SA stated that their training was lacking, and did not equip them with skills needed to execute their duties as occupational audiologists.

"We only had, we had one section, part of a whole thing that we had. It was a handout. It was a section of that handout. So we didn't have much training in that and we didn't have any practical training. So the knowledge I have, I accumulated after I graduated. (P4)

P7 shared a similar experience:

"It's tricky - yes and no. No in a sense that it was limited. We only did a small module on occupational audiology. It was a small project... assignment. It was the only exposure we had on occupational audiology in terms of occupational noise exposure. So we were not given information on methods to test for noise. We were not given information on how to prevent noise, what types of noise protection devices available. Yes, in a sense that we were given just a module. So we had that exposure to say there is occupational noise. It exists in terms of people getting hearing loss from work. We did a project by going to a workshop where we measured noise levels and we gave them training on how to protect their ears, but it was not with complete understanding.

P 5 highlighted the impact of not being sufficiently trained*:*

"...and the audiologist, if they are not properly trained, doesn't know all the legislation, or if they are not sure what is [in] Section 171. You know if the audiologist makes the mistake, it does cost the mine. It probably will cost the mine a lot of money because if that person is malingering, and that audiologist doesn't know industrial audiometry, doesn't know that I must double-check everything, make sure about the threshold and they miss that, they will probably misdiagnose the percentage and that person will be compensated. So that's one thing I felt in my training in industrial audiology. It's a big responsibility for you as an audiologist.

P1 suggested the following:

> *Maybe there is a space to do a postgrad in Occupational Audiology. I have not heard of that. I don't see it as a programme or certificate that can be accorded to someone obviously because the demands of our society have not been looking into that. I think it would assist a lot in managing noise induced hearing loss throughout the industries. If we can find a way to ensure that audiologists are given that skill to contribute positively, because at the current moment there isn't a positive or valuable contribution that they can make.*

According to ASHA: "Ideally, all graduate audiology programs should emphasize hearing conservation by offering specialized courses and practicum experiences relevant to the skills and knowledge needed by the professional intending to work in the area of occupational hearing conservation. Audiologists-in-training should have extensive practicum experience in working on-site in an occupational setting under the supervision of an audiologist experienced in occupational hearing conservation. This practicum should include activities in all seven of the components of a model HCP" (American Speech-Language-Hearing Association, 2004).

Currently in SA, there are gaps in the training of occupational audiologists, as audiologists are trained over a period of 4 years and occupational audiology is not prioritized due to the country's high burden of disease. Limited training in occupational audiology has implications for audiologists in delivering quality service in the management of occupational noise in SA. In America, after obtaining a graduate degree in audiology audiologists interested in occupational audiology enrol for further certification to supplement their training and expand their skills and knowledge (American Speech-Language-Hearing Association, 2004). Audiologists have access to education programmes offered by professional associations such as ASHA, the National Hearing

Conservation Association, and the Acoustical Society of America (American Speech-Language-Hearing Association, 2004) to name a few. Some universities offer special curricula in occupational audiology to supplement their basic audiology program, with specialized courses and reference materials from other fields such as industrial hygiene, engineering, business, and public health (American Speech-Language-Hearing Association, 2004). Therefore, there is a need for local universities to evaluate their training programmes and to offer postgraduate courses to audiologists interested in pursuing a career in occupational audiology.

6.8 Conclusion

This study highlights important gaps in the role of occupational audiologists in HCPs in SA. The fact that occupational audiologists, whose scope of practice encompasses ONIHL, are only minimally and peripherally involved in developing and executing HCPs may play a significant role in the lack of progress towards the elimination of ONIHL. Locally, the audiology profession needs to deliberate on strategies to ensure that this area does not remain neglected. Professional bodies that regulate audiology and occupational health need to work together to ensure systematic and efficient provision of services to this part of the population. Additionally, universities training audiologists need to review their curricula to ensure that occupational audiology is afforded the same attention as other aspects of audiology.

6.9 Limitations and Suggestions for Further Research

These findings should be considered with an awareness of the limitations of the study. Firstly, the small sample size, which was recruited through snowball sampling, restricts the ability to

generalize these findings beyond the study sample. Future research on a larger representative sample, perhaps on audiometrists involved in HCPs in South African mines, may allow the issues uncovered in this study to be further explored. Additionally, confirmation and direct observation of practice through ethnographic studies is required.

CHAPTER 7. OCCUPATIONAL NOISE INDUCED HEARING LOSS IN SOUTH AFRICAN LARGE-SCALE MINES: EXPLORING HEARING CONSERVATION PROGRAMMES AS COMPLEX INTERVENTIONS EMBEDDED IN A REALIST APPROACH



Of all the varieties of modern pollution, noise is the most insidious *(Robert Lacey, nd)*

Occupational Noise Induced-Hearing Loss in South African Large-Scale Mines: Exploring Hearing Conservation Programmes as Complex Interventions Embedded In a Realist Approach

(Reprinted with permission, see appendix I)

7.1 Abstract

Background: Complex interventions have been conducted in the field of public health to improve health at the individual, organizational policy or population level. In occupational audiology, hearing conservation programmes (HCPs), which are interventions to minimize or eliminate occupational noise-induced hearing loss, are currently not defined as complex interventions, despite them fitting the definition and features of complex interventions. Therefore, this study aimed to explore whether HCPs are a complex intervention, fitting the predefined criteria for complex interventions.

Method: A qualitative, descriptive research design was conducted using three sources of data – document analysis, interviews and systematic review to allow for triangulation. Data were collected through purposive sampling and qualitative content analysis was used for analysis.

Results: This study confirmed that HCPs are a complex intervention founded on solid and consolidated theories. Therefore, these results paved the way for realist reviews to be conducted in the mining sector in South Africa in order to understand the mechanisms influencing the success or failure of HCPs locally.

Conclusion: The success of HCPs in the mining sector depends on conducting contextually evidence-based evaluations such as realist reviews which can provide policy-makers with contextual evidence for why certain programmes do or do not work in certain settings.

Keywords: Hearing conservation programmes, complex intervention, realist reviews, occupational noise exposure, mining industry, South Africa

7.2 Background

In South Africa, hearing conservation programmes (HCPs) have been formally in existence for over two decades, since the declaration of the 1996 Mine Health and Safety Act. In 2003, the Mine Health and Safety Council (MHSC), comprising State, Employer and Labour representatives, circulated the 2003 MHSC milestones on the elimination of occupational noise induced hearing loss (ONIHL) in the mining industry with an aim to achieve these targets by 2014. These 2003 MHSC milestones had two targets. The first target stated that by December 2008, HCPs implemented by the industry must ensure that there is no deterioration in hearing greater than 10% amongst occupationally exposed individuals. The second target focused on the noise source, and stated that by December 2013, the total noise emitted by all equipment installed in any workplace must not exceed a sound pressure level of 110 dB(*A*) at any location in that workplace (including individual pieces of equipment)(Edwards & Kritzinger, 2012).

When the aforementioned milestones were evaluated at the end of 2013, it became apparent that the mining industry had not met all of the targets. Therefore, the 2003 milestones were revised. The revision of the 2003 milestones saw refinement and more specificity in the targets, which made the milestones seem more measurable. Firstly, as far as deterioration in hearing is concerned, the new target specifies that by December 2016, no employee's standard threshold shift (STS) will exceed 25 dB from baseline when averaged at 2000, 3000 and 4000 Hz in one or both ears. Secondly, regarding the noise source, the revised milestones state that by December 2024, the total operational or process noise emitted by any equipment must not exceed a milestone sound pressure level of 107 dB(*A*) (MHSC).

A close look into these milestones revealed a significant flaw evident in these milestones. This flaw could arguably be the key reason for the failure of the South African mining industry to

meet the targets. Firstly, the targets focus on only two aspects of noise conservation; hearing deterioration and noise source. These two aspects are the responsibility of mine management. A key stakeholder, the mineworker, has not been included in the targets at all. One could argue that education of and buy-in from the mineworkers with regards to hearing conservation is key to the success of any intervention involving the miners. Therefore, careful deliberation should occur around the role of mineworkers in the setting of targets, if HCPs are to succeed. Secondly, the sequencing of the two targets (hearing deterioration and noise source) appears incongruent to the goal. Reduction of noise from the noise source should come prior to the expectation of reducing the deterioration of hearing loss. These milestones, as currently stated, appear to expect the opposite. That is, there must be a reduction in deterioration of hearing loss in miners at least 5-8 years before the reduction in the level of intensity of the noise source causing the hearing loss. Lastly, the 2014 milestone revisions, which acknowledged the failure to meet the 2003 milestones, increased the time frame of reducing noise from the noise source from 5 years to 8 years. This seems to indicate serious challenges with this target, which the current author believes is key towards eliminating ONIHL.

Challenges in meeting milestones have implications for ONIHL within the South African mining industry. For instance, in 2013, statistics on ONIHL as recorded by the Department of Mineral Resources indicated that, on average, 1 600 cases of NIHL are reported each year (Booyens, 2013). An unpublished study conducted to understand stakeholders' perceptions of the HCPs implemented in the South African mining industry. This study sought to understand the reasons leading to the revision of the 2003 MHSC milestones. Findings of this study highlighted challenges with the implementation of the 2003 MHSC milestones. These challenges included

poorly defined action plans, lack of cohesive engagement and collaboration with all stakeholders; with exclusion of some stakeholders, from formulation to implementation of these milestones. These challenges raise important implications for the success of any intervention programme.

Current evidence suggests that HCPs implemented in the South African mining industry are currently not achieving the desired results. It is the author's belief that studies conducted on the presence and management of ONIHL in the mining sector will continue to yield the same unsatisfactory results if careful strategic and contextually relevant changes that adopt realist reviews within a complex intervention position are not considered. There are therefore calls for new, innovative and evidence based ways of managing excessive exposure to hazardous noise in the mining industry. There is a need for approaches that will focus on holistically understanding why HCPs are not successful in the South African mining industry, while their counterparts in developed countries have reported success. One such approach is a realistic review of the HCPs currently implemented in the South African mining industry.

Realist reviews are fundamentally concerned with "understanding and unpacking the mechanisms by which an intervention works (or fails to work)" (Rycroft-Malone et al., 2012, p. 1). Realist approaches focus on theory development while taking into consideration the context when methodically and transparently synthesizing results (Pawson, 2006; Pawson et al., 2005; Rycroft-Malone, McCormack, DeCorby, & Hutchinson, 2010). A realist review, although a relatively new methodological strategy (Pawson et al., 2005), can assist in explaining why HCPs implemented locally are currently failing to achieve the set targets. Benefits of conducting realist reviews include, firstly, providing stakeholders and policymakers with enlightenment and empirical evidence on the nature of the programme or intervention implemented in a given setting (Pawson et al., 2005). Secondly, realist reviews assist policy-makers to interpret and clearly

understand why a programme worked better in one context than another, e.g. international vs local context. Thirdly, realist reviews provide policymakers with a justification for taking one course of action over another. Lastly, realist reviews alert policy-makers to potential problems and specific measures that can be applied to mitigate potential problems. Moreover, realist reviews provide explanations rather than judgements around interventions (Pawson et al., 2005).

Realist reviews are conducted to review complex interventions (Berg & Nanavati, 2016; Cooper, Lhussier, Shucksmith, & Carr, 2017; Fletcher et al., 2016; Kirst M. & O'Campo, 2012; Willis et al., 2016). Complex interventions are defined as interventions built from multiple interacting components, which may act both independently and interdependently (Medical Research Council, 2000; Moore et al., 2015). These components may include behaviours, behaviour parameters and methods of organizing those behaviours, and they may have an effect at an individual level, organizational level or population level (Datta & Petticrew, 2013). Complex interventions are generally conducted to improve health either at the individual, organizational policy or population level in different fields such as public health research, medical research (Moore et al., 2015) and any public services dealing with complex social interventions such as performance measures, regulations and inspection or funding reforms (Pawson et al., 2005).

In the field of occupational audiology, complex interventions have not been conducted even though research widely demonstrates both the auditory and non-auditory health impacts of excessive exposure to occupational noise in the workplace (Ahmed, 2012; Basner et al., 2014; Delecrode et al., 2012; Shendell, Barnett, & Boese, 2004). Furthermore, the fact that HCPs are "built from multiple interacting components, which act both independently and interdependently" from each other makes them well suited to complex interventions (Shiell, Hawe, & Gold, 2008, p. 1281). Hence, the current study aimed to explore whether HCPs are a complex intervention, fitting

the predefined criteria for complex interventions described by Pawson et al (Pawson et al., 2005) as follows:

- Complex interventions are theories.
- Complex interventions are active and able to achieve their effect through the active involvement and engagement of individuals.
- Complex interventions are comprised of long journeys.
- Complex interventions are non-linear in their implementation chains, and can even go into reverse.
- Complex interventions are fragile and embedded in multiple social systems.
- Complex interventions are prone to be borrowed.
- Complex interventions are open systems that feedback on themselves.

7.3 **Methodology**

A qualitative, descriptive research design was adopted as this study used existing data to explore the complexity of HCPs. A qualitative descriptive approach was selected because of its cardinal features. Firstly, it allows the use of a range of theoretical orientations. Secondly, it allows the use of any purposive sampling technique. Thirdly, it allows the use of document reviews, and semi-structured interviews to collect data. Fourthly, it allows the use of content analysis as an analysis technique. Lastly, it allows the provision of a descriptive summary organized in a way that best fits the data (Jiggins Colorafi & Evans, 2016; Sandelowski, 2010). All of these aforementioned features were adopted in the current study.

7.3.1 Sampling strategy

Purposive sampling was utilized in this study as it allowed the researcher to use the data previously collected and readily available to the researcher. Data were obtained from three sources: (a) interviews with the stakeholders in the South African mining sector, (b) document analysis of the regulations on ONIHL in the South African mines, (c) a literature review of original research on the management of ONIHL in the mining sector. Therefore, the use of purposive sampling was ideal in that it allowed the research, according to Etikan et al. (2016), to identify and select individuals and groups of individuals who have experience and are knowledgeable on the management of ONIHL in the mining industry. Furthermore, the researcher sought to recruit participants who are available and willing to participate in the current study. Also, the researcher used documents that are readily available online.

7.4 Sources of data

7.4.1 Interviews with various stakeholders

The first source of data was obtained from interviews conducted with 15 stakeholders who are involved in the management of ONIHL in the South African mining sector. These participants consisted of audiologists, ventilation and occupational health engineers, occupational hygienists and representatives of the state, labour and employer. These participants were identified from the websites of the companies affiliated with the mining industry. Participants were contacted by telephone and via email to request them to participate in the study. The interviews were conducted both face to face and by telephone, depending on the availability of participants. Interview questions were formulated by the researcher and focused on the specific roles of the participants,

the objectives of the mining industry with regard to the management of ONIHL and the challenges and progress since the formulation to the evaluation of the HCPs in the mining sector.

7.4.2 Document analysis

The second set of data was obtained through the document analysis of the Acts, regulations, policies, and guidelines on the management of ONIHL in the South African mining sector since 1994. Websites of the companies affiliated to the mining industry were searched for the aforementioned documents. The search yielded eight documents (Table 1) which accurately focused on the complexity of HCPs in the mining sector. Documents included and analysed in this study were from 1994 to date with a focus on occupational health and safety in the mining industry in South Africa.

7-1: - Table 1: Document analysis data

Document number	Name of document	Year promulgated	Reference
1	Commission of Inquiry into Safety and Health in the Mining Industry	1994	(Stanton, 2003)
2	Mine Health and Safety Act, 1996 (Act No. 29 of 1996)	1996	(President's office, 1996)
3	South African mining industry journey to zero harm 2003-2013	2014	(Mine Health and Safety Council, 2014b)
4	Audiometry in the workplace	2011	(SASOM, 2011)
5	Noise-induced hearing loss regulations No. R. 307 – 7	2003	(Government Gazette, 2003)
6	Guideline for the compilation of a mandatory code of practice for an occupational health programme (occupational hygiene and medical surveillance) for noise	2003	(Mine Health and Safety Inspectorate, 2003)
7	Guidelines for a hearing Conservation programme	2003	(de W Oosthuizen, 2006)
8	2014 mine Occupational Health and Safety summit: Every mine worker returning from work unharmed every day striving for zero harm	2014	(MHSC, 2014a)

7.4.3 Systematic review

The last set of data emerged from a systematic review of literature on the management of ONIHL in the African mining industry. The literature search yielded nine articles that met the inclusion criteria. Of the nine articles, seven were conducted in South Africa while of the remaining two; one was conducted in Ghana and the other in Zimbabwe. Therefore, seven articles (Table 2) from the South African mining sector were included in the final sample**.** These articles were from 1994 and had a focus on the management of ONIHL in the mining industry.

7-2: - Table 2: Systematic review articles

Author(s) & Date	**Research title**
Edwards, A.L.; Milanzi, L.A.; Khoza, N.N.; Letsoalo, M.S, &Zungu, L.I. (2015)	Evaluation of the current practices of noise-induced hearing loss (NIHL) awareness training in the South African mining industry
Gumede, H.; Blomerus, K.; Coutts, D. & De Beer, J. (2014)	Strategy towards a mining industry-wide Buy-and-Maintain Quiet initiative to reduce noise induced hearing loss
Ntlhakana, L; Kanji, A; Khoza-Shangase, K; (2015)	The use of hearing protection devices in South Africa: exploring the current status in a gold and a non-ferrous mine
Steenkamp, R.J (2008)	A personal approach to hearing conservation: the key to effective second-level noise control
Amedofu, G. K. (2007);	Effectiveness of hearing conservation program at a large surface gold mining company in Ghana.
Mutara, G. & Mutanana, M (2015)	An Analysis of a Hearing Conservation Programme (HCP) at a Mining Company in Zimbabwe
Steenkamp, R.J(n.d)	A six sigma-based management model to eliminate the noise-induced hearing loss pandemic in South African mines
Hansia, M.R. & Dickinson, D. (2010)	Hearing protection device usage at a South African gold mine
Burger, NDL; Von Wielligh, AJ; De Wet, PR; Otterman, RW & Steyn, JL; (2004)	Design and development of a low noise rock drill

7.5 **Ethical considerations**

The author declares that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guidelines on human experimentation. Ethical approval

was obtained from the University's Medical Ethics Committee (Protocol number **M160264**). Participants were informed regarding confidentiality, anonymity and the right to withdraw from the study without any negative consequences to the participants.

7.6 Trustworthiness

Trustworthiness and credibility of the findings were achieved through triangulation as three sets of data were used in this study. Triangulation allowed for the collaboration of findings across different sets of data, thereby reducing the impact of potential biases that can exist in a single study (Bowen, 2009). Furthermore, since the researcher is an audiologist, to guard against any bias towards the findings of the study, the researcher used a peer reviewer.

7.7 Data analysis

A qualitative content analysis approach was adopted as it allowed for a systematic and objective means to make valid inferences from verbal, visual or written data in order to describe and quantify specific phenomena (Bengtsson, 2016). Deductive content analysis is used in cases where the researcher seeks to retest existing data in a new context in order to test categories, concepts, models or hypotheses (Elo & Kyngas, 2008). Therefore, this study adopted a deductive content analysis method recommended by Elo and Kyngas (2008) viz. developing a structured analysis matrix, data coding according to categories and hypotheses testing and correspondence comparison to earlier studies. Results were then presented in line with the features of complex interventions as described by Pawson et al. (Pawson et al., 2005).

7.8 Findings and discussion

Typically, in qualitative content analysis, supporting evidence supporting is presented in the form of quotations, excerpts, quotation and passages as recommended by Labuschagne (Labuschagne, 2003). However, in this current study, the findings are summarized as some of the excerpts are lengthy, Readers will be directed to where they can find the full document should they require the original full text.

Feature 1: Complex interventions are theories

According to Pawson et al (Pawson et al., 2005), complex interventions are based on hypotheses that are causal in nature. This statement implies that, for instance, if a certain evidence-based programme is implemented, specific results are expected. According to Document 1 entitled "Report of the Commission of Inquiry into Safety and Health in the Mining Industry" (Stanton, 2003) (Table 1), HCPs were implemented in the South African mining industry post a lengthy deliberation among various stakeholders who were tasked with addressing the challenge of poor occupational health and safety in the workplace. Consequently, the 2003 MHSC milestones and the revised 2014 milestones were implemented to eliminate occupational noise in the mining industry as detailed in Documents 1 and 2 (President's office, 1996; Stanton, 2003) (Table 1). It is therefore clear that implementing the MHSC milestones was a move towards the elimination of ONIHL. It can therefore be argued that the implementation of MHSC milestones was informed by the hypothesis that if HCPs, through the milestones, are implemented, then elimination of ONIHL can be achieved. Therefore, this assertion serves as the causal hypothesis or theory supporting the implementation of HCPs in the South African mining industry in order to protect the health and safety of persons at the mines. This finding is in line with that of Pawson et al. (Pawson et al.,

2005), who concluded that interventions are theories based on a hypothesis which postulates that if one delivers a programme in this way or one manages services in this manner, then this will bring about some improved outcome. Therefore, this postulation is in line with the premise that if the mining industry implements HCPs taking into account the context of the mine, it is possible to eliminate excessive noise exposure in the mines and thereby achieve the desired outcome. Furthermore, findings from the systematic review also support the importance of having a solid and consolidated theoretical plan when implementing HCPs as a failure to have a solid and consolidated foundation can negatively influence the success of HCPs.

Feature 2: Complex interventions are active

Complex interventions are active, meaning that they achieve their effects through active participation and input from various stakeholders involved in that particular programme. Authors such as (Brown, Bradley, Ng, Colwell, & Mathers, 2014) and (Hawe, (2015) view complex interventions in terms of how interventions work, meaning what are the active ingredients components of the programme and how these ingredients exert their effect. Brown et al. (2014) list three important ingredients or components of active complex interventions: (a) active components assist in raising awareness of the key issues in the choice of intervention preferred; (b) active components improve the knowledge pertinent to decision-making; (c) active components provide preparation for the involvement of various stakeholders in the consultation.

To highlight these components, the same Document (Stanton, 2003) (Table 1) reveals that the mining industry is aware of the consequences of unmanaged excessive noise in the workplace, hence the implementation of HCPs through the 2003 and 2014 MHSC milestones as the intervention of choice. The following statement supports these findings: “the mining industry is

not making the desired progress with noise-induced hearing loss, which is a major occupational health concern. As an industry, we have committed to the massive reduction and elimination of occupational noise induced hearing loss" (Booyens, 2013, p. 1). With regard to improving the knowledge pertinent to decision making and involvement of stakeholders in consultations, Document 3 entitled "South African mining industry journey to zero harm from 2003-2013 (Mine Health and Safety Council, 2014a), (Table 1) reveals that *"The road to attaining Zero Harm is a long, winding and bumpy one. However, it is a road that is walked alongside diverse people collaborating, executing plans and strongly rallying around a common objective"* pg. 9. From this excerpt, arguably, the stakeholders involved in the formulation and implementation of HCPs in the mining sector have engaged and collaborated with different stakeholders in order to select the best and evidence-based intervention to eliminate noise in the mining industry. Data obtained from various stakeholders also confirmed continual collaboration and consultation of different stakeholders depending on the task at hand.

Feature 3: Complex intervention are comprised of long journeys

Complex interventions have long journeys, meaning they begin in the heads of policy architects, pass into the hands of practitioners and managers, and (sometimes) into the hearts and minds of the end users (Pawson et al., 2005). As alluded to in the previous section, this feature speaks to the effect that interventions are typically a long process from conceptualization to evaluation. Holmboe (2018, p. 351) states "the journey to change takes time". This was evident in this study as findings from Document 1(Stanton, 2003) (table 1) revealed that before the formalization of HCPs in South Africa, the then President of the country appointed a task team, referred to as the Leon Commission, to address health and safety concerns in the mining industry. Through

deliberations of this committee, a Mine Health and Safety Act 29 of 1996 (President's office, 1996) was established to provide a comprehensive legal framework for creating a healthy and safe working environment. Subsequently, in 1997, the MHSC was established. This led the development of the 2003 MHSC milestones on eliminating ONIHL. These milestones underwent the Presidential health and safety audit in 2008 and were ultimately revised in 2014.

The findings presented clearly illustrate the journey and process that was undertaken to formally implement HCPs in the mining sector. In addition, it is clear that the idea of introducing HCPs in the mining sector started with the President, and this idea was passed on to various stakeholders and eventually, the stakeholders who implemented the milestones were not necessarily the individuals who developed the milestones themselves. Furthermore, data obtained from the interviews also highlighted the same sentiments reported in Document 3 (Mine Health and Safety Council, 2014), (Table 1) indicate that the process was in progress when these stakeholders were roped in and that the process is still continuing, hence the latest milestones will be evaluated in 2024. The length of time it has taken for the conceptualization, implementation, evaluation and revision of milestones appears to be significantly long. The process from formulating to evaluating the HCP journey in the South African mining industry has taken a long journey, whose end may not be near. However, it is hoped that this journey brings out the desired outcome.

Feature 4: Complex interventions are non-linear in their implementation chains

According to Pawson et al. (2005), complex interventions are non-linear and can even go into reverse. Complex interventions are built from multiple interacting components, which may act both independently and interdependently, and include behaviours, behaviour parameters and

methods of organizing those behaviours, and they may have an effect at an individual level, organizational level or population (local society) level (Datta & Petticrew, 2013; Shendell et al., 2004). It is therefore no wonder that complex interventions are non-linear and they may even go into reverse. This was evident in this current study as data obtained from Document 2 entitled Mine Health and Safety Act, 1996 (Act No. 29 of 1996) (President's office, 1996), (Table 1) revealed that, initially, the 2003 MHSC milestones were concerned with the eliminating ONIHL by focusing on monitoring the percentage of hearing loss (PHL). However, with further consultation and involvement of other stakeholders along the way, the focus council changed from using PHL to monitoring the STS. Hence, the milestones were revised to incorporate the changes identified by the stakeholders. Furthermore, the initial milestones also targeted limiting total noise emitted by all equipment installed in any workplace not to exceed a sound pressure level of 110 dB(*A*) at any location in that workplace (including individual pieces of equipment). Through consultations and studying the progress from developed countries such as Canada, noise emission was then reduced further to 107 dB(*A*). These findings attest to the importance and the impact of continual engagement among stakeholders in order to improve in

Feature 5: Complex interventions are fragile

Complex interventions are fragile creatures, and are often embedded in multiple social systems. Furthermore, complex interventions are rarely, if ever, equally effective in all circumstances because of the influence of context (Pawson et al., 2005). The observations that complex interventions are rarely equally effective in all situations due to contextual factors was evident in this study. For instance, in this current study, interviews with stakeholders revealed that some mines were able to meet the targets while others were unable to meet these milestones. The scales

(large vs. small) of the mines, the culture of the mines and the active involvement of stakeholders were cited as some of the factors that influence the success of the milestones. Therefore, the size of the mine and the availability of resources and level of support and commitment from all stakeholders may contribute to the fragility of the implemented programmes. Furthermore, social systems have an impact on the success of programmes, therefore having a buy-in from all departments and systems is crucial in the success of HCPs. As already mentioned, social systems may influence the outcome of implemented interventions. Therefore, it is important to consider social systems and their impact on the programme. For instance, from the interviews conducted and systematic review results, the role of mineworkers in the management of ONIHL was not overtly communicated. It is important to include mineworkers as they are directly exposed to the noise, their participation and buy-in may be a critical step in achieving the desired outcomes.

Feature 6: Complex interventions are prone to be borrowed

Complex interventions are leaky and prone to be borrowed. Pawson et al. (2005), state that, when it comes to putting flesh on the bones of an intervention strategy, practitioners will consult with colleagues and cross-fertilize ideas. In engaging with various stakeholders, it is important to acknowledge that "transparent and meaningful consultation with key stakeholders is a cornerstone of informed decision-making and good governance" (Reidar, 2017, p. 1). Consultation allows for cross-fertilization of ideas and knowledge which influences stakeholders on communal decision-making by allowing stakeholders to communicate their individual knowledge to other stakeholders in order to reach a mutual decision to execute the cross-fertilized idea that is best suited in accomplishing a given task (Gunasekaran, Mostafa, Ahmad, & Tang, 2017). In the current study, the consultation and the cross-fertilization of ideas was evidenced by engaging various

stakeholders with an aim of implementing evidence-based interventions. Therefore, in this study, the initial MHSC milestones were focused on and concerned with PLH shifts as opposed to STS. Through consultation and further engagements with other stakeholders, the milestones were revised to focus on STS as it was rationalized that this was the best strategy to monitor and thereby eliminate ONIHL in the mining sector. The following quotation from one of the stakeholders who participated in the interview summarizes the process below:

> "*For instance, when we were working towards the 2014 milestones, the new milestones, then we got in an audiologist you know because we were debating for instance, should we use the PLH (percentage of hearing loss) shift or should we use the STS (standard threshold shift) as a way of early detection of noise. So an audiologist from an academic institution was invited and she went through the cons and the pros and in the end, we are agreed as the industry that we will shift from PHL shift to STS. So that's what the new milestones are based on STS".*

This quote highlights the importance of consultation and cross-fertilization of ideas. Through the engagement of stakeholders, opportunities to improve the quality of HCPs in the mining industry were realised. Document 3 also supports the importance of collaboration: *"The following aspects are critically important to reach the target of Zero Harm: the right mind set, correct action and strong support from stakeholder. Working together, the South African mining industry has achieved major successes*" pg. 5. Having a common goal and allowing for consultations and interrogation of ideas will indeed yield favourable outcomes.

Feature 7: Complex interventions are open systems that feedback on themselves

The final feature of complex service interventions is that they are open systems that feedback on themselves. As interventions are implemented, they change the conditions that made them work in the first place (Pawson et al., 2005). According to Cooper et al. (2017) complex interventions do not act as independent agents for change, rather, they operate within open systems, interacting with personal, interpersonal and environmental factors outside of the programme. Complex interventions are multifactorial systems which are interconnected, changes in one part of the system feed through other parts of the system and feedback on themselves (Shiell et al., 2008). Therefore, learning occurs that alters subsequent receptivity to interventions, which ultimately leads to unintended effects in the longer term (Pawson et al., 2005). Data from the current study indicated that HCPs are manipulated or affected by factors outside the programme itself. For instance, due to poor socio-economic status and low wages for mines, some stakeholders revealed that some workers expose themselves to excessive noise in the workplace in order to be compensated for incurring a hearing loss in the workplace. Other stakeholders expressed that most mines use production incentives for production, therefore, some workers may expose themselves to excessive noise in order to meet the production targets and get a bonus. This revelation by stakeholders also highlighted the importance of educating the workers about the long-term effects of exposure to excessive noise in the workplace.

7.9 Conclusion

The aim of this study was to explore whether HCPs are a complex intervention, fitting the predefined criteria for complex interventions described by Pawson et al. (2005). The analysis of

documents, systematic review and interviews from stakeholders provides evidence for the complexity of HCPs currently implemented in the South African mining industry.

The findings revealed that HCPs are, firstly, based on a theoretical premise which states that implementation of HCPs will bring about the elimination of ONIHL in the mining industry. Secondly, formulating, implementing monitoring and evaluating HCPs involved participation of various stakeholders, thus making them active complex interventions. Thirdly, HCPs were formulated in 1994 and are still ongoing, thereby making them complex interventions with long journeys. Fourthly, HCPs comprised multiple pillars, which act both independently and interdependently; hence, making them non-linear complex interventions. Fifthly, HCPs are influenced by the context, such as the size of the mine, the resources available and the culture of the mine, thereby making them fragile complex interventions. Sixthly, the implementation of HCPs has been influenced by continual consultation and cross-fertilization of ideas, therefore making them complex interventions prone to being borrowed and refined. Lastly, HCPs are affected by personal, interpersonal and environmental factors outside of the programme, thereby making them open systems that feedback on themselves.

Much energy and dedication has been fuelled towards achieving the best outcomes; however, the outcomes are still not satisfactory. It is clear that the journey towards elimination of ONIHL in the mining sector is still far from being over. There is therefore a need for the mining industry to focus its energies on new and innovative ways of understanding why some aspects of the HCPs currently implemented yield desired outcomes while some do not. There is therefore a need to implement studies focusing on the context of each mine to improve HCPs in individual mines as opposed to implementing a HCP for all mines as a blanket approach.

Failure to recognize HCPs as complex interventions has implications, not only for the individuals exposed to noise, but for their colleagues, families, companies and the state at large. Arguably, exposure to excessive noise is not life threatening; it is, however, health threatening. Therefore, there is an urgent need to recognize HCPs as a complex intervention in order to conduct a realist review on the status quo of noise management in South Africa as a developing country.

In conclusion, the findings of this study have shown the complexity of HCPs, which was a necessary step in moving towards embarking on conducting realist reviews in the locals mines to understand what works for which mine under what conditions. Therefore, current findings pave the way for mines to conduct realist reviews, now that it has been confirmed that HCPs are complex interventions needing realist reviews to understand their mechanisms.

CHAPTER 8. A FEEDBACK - BASED NOISE-MONITORING MODEL: A PROPOSED MODEL OF MANAGING OCCUPATIONAL NOISE INDUCED HEARING LOSS IN THE MINING SECTOR IN SOUTH AFRICA



No job is so important and no service is so urgent that we cannot take time to perform our work safely *(Frasi Belle)*

A Feedback- Based Noise-Monitoring Model: A Proposed Model of Managing Occupational Noise Induced Hearing Loss in the Mining Sector in South Africa

8.1 Abstract

Occupational noise induced hearing loss (ONIHL) has been classified as the leading work-related disability in the mining industry. ONIHL has a negative impact, on not only the health and occupational productivity of the individual exposed to excessive noise, but also to the industry and the nation's economy. Hearing conservation programmes (HCPs) are an effective strategy in the management of ONIHL. However, current literature indicates that HCPs are not achieving the anticipated and desired outcomes despite the efforts focused on the management of ONIHL in the mining sector. Efforts to eliminate excessive noise exposure in the mining industry are thwarted by industry's failure to implement effective HCPs in the mining sector. Current evidence indicates that there is an overreliance on mainly hearing protection devices (HPDs) in the management of exposure to occupational noise; while neglecting or undermining the other pillars of the HCPs aimed at reducing ONIHL. Consequently, ONIHL continues to be a public health concern in the South African mining industry. There is, therefore a need to explore other methods that can enhance efficiency and effectiveness of HCPs currently implemented in order to avoid the negative consequences of this epidemic in the workplace. Thus, this paper introduces a feedback- based noise monitoring model as a tool to manage noise exposure. This feedback-based model is based on a noise management matrix, which was adapted from a risk management matrix. Preliminary results were used to demonstrate the application of the model.

Keywords: occupational noise, hearing loss, mining industry, matrix, model, policies, conservation, programmes, South Africa, protection devices, monitoring, feedback

8.2 Introduction

The presence of excessive noise in the workplace may result in individuals exposed acquiring a disabling hearing loss. A hearing threshold below 40dBs is classified as a disabling hearing loss (Yadav et al., 2015), an invisible condition that does not readily manifest itself (Tye-Murray ,2009). Dugan (2003) describes disabling hearing loss as the 'most prevalent, least recognized and least understood physical disability' (p 3); while Copley and Frederichs (2010) argue that permanent disabling hearing loss is a major contributor to the global burden of disease on individuals, families, communities and countries. Exposure to excessive noise in the workplace may lead to acquiring ONIHL, a 'partial or complete hearing loss in one or both ears as a result of one's employment' (Nandi and Dhatrak, 2008, p.1). ONIHL develops gradually as a result of being exposed to continuous or intermittent high levels of noise 85dBA over a long period of time (McBride, 2004, Patel et al., 2010, Rappaport and Provencal, 2001). Usually, ONIHL ranges between 40dB in the low frequencies to under 70 dB in the high frequencies (Al-Otaibi, 2000, Edwards, 2009); therefore rendering it a disabling hearing loss. ONIHL is a prevalent condition in the mining industry and has been classified as the leading work-related disability, and the second most common form of acquired hearing loss after presbycutic (age-related) hearing loss with severe consequences for those exposed to high levels of noise (Ritzel and McCrary-Quarles, 2008).

Impact of ONIHL on the individual

A mild hearing loss may have a profound impact on the exposed individual. For instance, the safety of the exposed individual may be profoundly compromised, resulting in work related injuries, (Amjad-Sardrudi et al., 2012). Furthermore, prolonged exposure to hazardous noise in the workplace can potentially lead to increased fatigue and decreased concentration, which ultimately

increases human errors (Amjad-Sardrudi et al., 2012; Picard et al., 2008). Additionally, excessive noise exposure can potentially reduce the worker's ability to perform or complete tasks that are dependent on auditory signals or verbal communication significantly (Thorne, 2006), subsequently resulting in a communication handicap, which, ultimately, will impact on team work and group productivity (Momm & Geiecker, n.d)

Socio economic impact of ONIHL

Occupational injuries, ill health and absenteeism have enormous social and economic implications for individuals, their families, communities, and the Nation at large (reference). Economically, there are direct and indirect costs for the society and the Nation (Hermanus, 2007). For instance, it is approximated that the total costs for occupational accidents and disease are between 1 and 3% of Gross Domestic Product (GDP) in various countries (Rikhardsson, 2004, Leigh et al., 1992). Direct costs of occupational injuries include: compensation costs, costs associated with damage in the workplace, and the cost of interruption of production; while indirect costs include: the cost of livelihoods lost and loss of income to dependents (Hermanus, 2007). According to Hong et al. (2013) the impact of ONIHL on one's health and quality of life cannot be quantified in tangible measures or standards; although the compensation cost for ONIHL is consistently increasing. Statistics on the burden of ONIHL in developing countries is not readily available (Nelson et al., 2005) however, Chadambuka et al. (2013) argue that 80% of individuals affected by ONIHL reside in low and middle income countries where ONIHL presents a "much heavier burden than in developed regions of the worlds". In South Africa, Rand Mutual Assurance (RMA), insures approximately 80% (340 000) of the mining industry; and receives and processes roughly 50 000 (12%) claims for occupational injury and disease associated with ONIHL annually (Reference).

This cost is estimated at R15 000 per person annually (Begley, 2004). Based on the analysis of the costs of NIHL claims in a study conducted by Edwards and Kritzinger (2012) RMA has paid over millions of rands towards compensation for ONIHL from 1998-2007.

Management of ONIHL

A limited review of literature on the management of ONIHL in the mining sector shows that hearing conservation programmes (HCPs) are the most effective way of managing excessive exposure to hazardous noise in the workplace (References for this), especially, the hierarchy of control which when implemented correctly, is reported to lead to the reduction or elimination of excessive noise in the workplace (Figure 4).

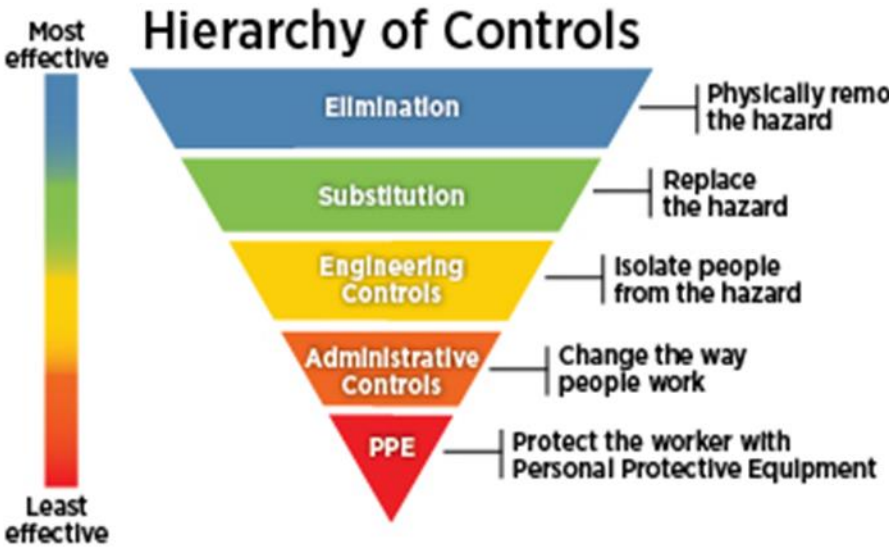


Figure 4: - HCP hierarchy of control

According to the HCP hierarchy (as depicted in Figure 4), engineering and administrative controls are the first line of defence in the management of hazardous noise in the workplace after elimination and substitution of the noise source. However, available evidence suggests that in practice, engineering and administrative controls are not given first priority (Suter, 2012). Locally, there is a slow uptake in implementing engineering controls as the chief strategy in the management of ONIHL (Moroe et al 2018). One of the main reasons for the slow uptake is that acquiring machinery for engineering controls is reported to be very expensive (Rupprecht, 2017).

Current international and local literature describes hearing protection devices (HPDs) as the most used form of protection against high levels of noise despite their proven inadequacy (Bruce, 2007, Bruce and Wood, 2003, Hong et al., 2013, Suter, 2012, Ntlhakana et al., 2015, Steenkamp, nd). Suter (2012) argues that there is no doubt that HPDs are helpful in reducing the impact of sound energy to the ear, however, they can be most effective when used in conjunction with engineering and administrative controls and other HCP pillars. The main reason HPDs alone are ineffective stems from concerns such as discomfort, improper sizing, poor hygiene and the inability to hear speech and warning signals when using them (Suter, 2012). Hence South African literature indicates that HCP are still not successful (Edwards and Kritzinger, 2012, Sliwinski-Kowalska and Davis, 2012, Bomela, 2005, Ntlhakana et al., 2015, Steenkamp, nd). Moroe et al. (2018) conducted a systematic literature review on the management of ONIHL in the mining sector in Africa. The findings of the systematic review indicated that majority of the studies conducted on the management of ONIHL focus on the use of HPDs. In addition, there was a dearth of studies on comprehensive holistic HCPs analysis and evaluation. These findings suggest a need for innovative and cost-effective means to enhance the HCPs implemented in the mining sector

such as the proposed noise management matrix, which is an example of a risk management tool that has yielded positive outcomes for many industries. The purpose of this study is to introduce a noise management matrix as a tool of managing ONIHL within the context of the South African mining sector.

A noise management matrix, which will be detailed below, is defined as a risk management tool which can be used in various industries such as the defence force and corporate to successfully manage identified risks (reference). In this paper, this noise management matrix has been converted to a feedback- based noise monitoring model. A control engineering approach is then used to formulate the mining noise occupational policies as a control law. Currently, a basic feedback model, still to undergo further refinements, has been designed and used to provide preliminary results to illustrate the use of the model in this paper. The potential value of this paper can be measured in terms of possible significant savings in occupational noise induced hearing loss compensation claims and also contribute towards the quality of life of the people exposed to excessive noise in the workplace.

8.3 **Introducing a noise management matrix**

Risk matrices have been used for years to rank different risks in the military (Donoghue, 2001) and recently, practitioners, academics and the business community has shown an interest in risk management (Dabari and Saidin, 2014). This interest stems from the ability of risk management to promote organisational outputs and create measureable value for stakeholders (Gates et al., 2012). Risk is defined as "the probability that a particular adverse event occurs during a stated period of time or results from a particular challenge" (Elmontsri, 2014). Not all risk can be eliminated thus creating a challenge of how much risk is acceptable and how to manage residual

risk (Elmontsri, 2014). Dabari and Saidin (2014) define risk management as "a systematic approach that aligns strategy, people, technology, processes and knowledge with the purpose of assessing, evaluating and managing the risk that an organisation faces"; while Elmontsri (2014) defines risk management as the process of 'reducing the risk to a level deemed tolerable by society and to assure control, monitoring, and public communication'. For the purpose of this study, the authors adopted the definition by Elmontsri (2014) since the authors recognise that in some contexts, such as the mining industry, the risk of noise as a hazard cannot be entirely eliminated.

"Risk assessment is the scientific process of defining the components of risk in precise, quantitative terms in order to specify what is at stake, calculating the probabilities of both the wanted and unwanted consequences and averaging these components by multiplying the probabilities by the impact of the effects" (Elmontsri, 2014, Kolluru and Brooks, 1995, pg 50). Risk assessments can be qualitative or quantitative (Elmontsri, 2014). Cox et al. (2005) assert that quantitative risk assessment, where the risk from a scenario is reported numerically, allows the assessor to define the absolute risk measured on any chosen unit or scale making the conclusions or judgements objective. Qualitatively, the risk from one scenario or group of scenarios can be generalised to other scenarios thus making it subjective (Cox et al., 2005).

Therefore, using the description of risks assessment aforementioned, a feedback-based model for monitoring noise induced hearing loss in the mining sector was developed. Below, the authors will discuss four steps involved in implementing a risk management matrix in the workplace. These steps are:

1. The development of the feedback system
2. System description
3. Application of the feedback model: Preliminary Results

8.4 **Development of the feedback model**

An engineering control approach was applied to the noise management matrix (Figure 2) which was adapted from the risk management matrix (Figure 3).

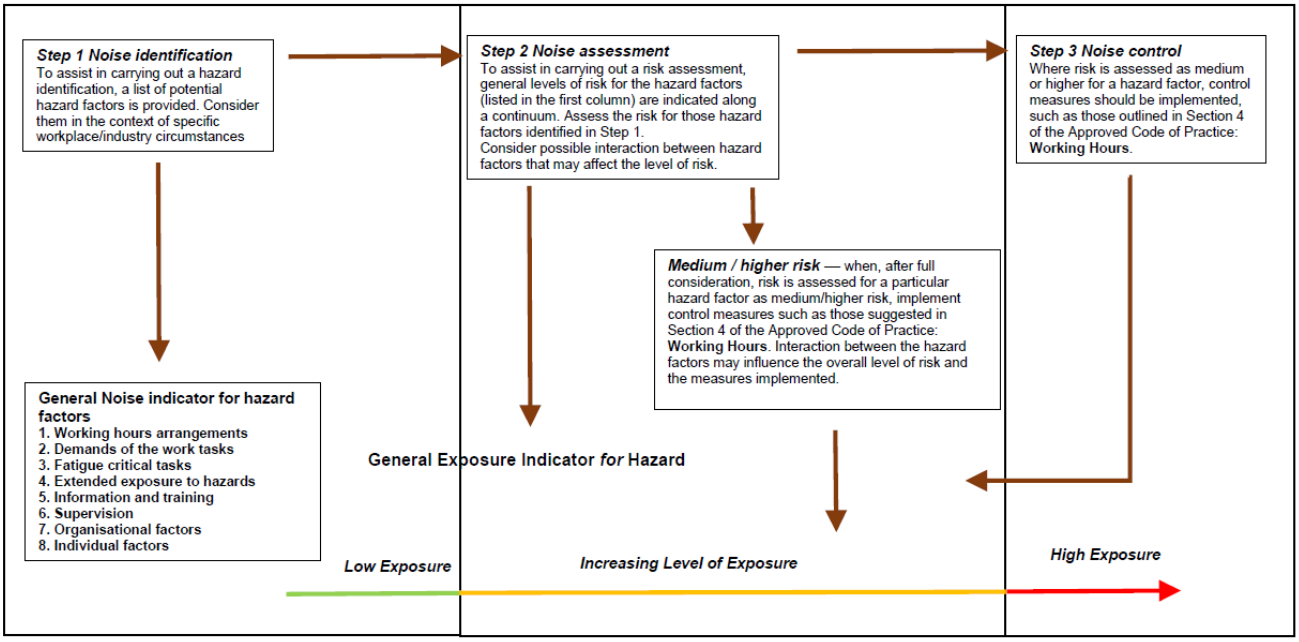


Figure 5: - Noise management matrix. Adapted from the Risk Management Matrix

(EasyOHS, n.d.)

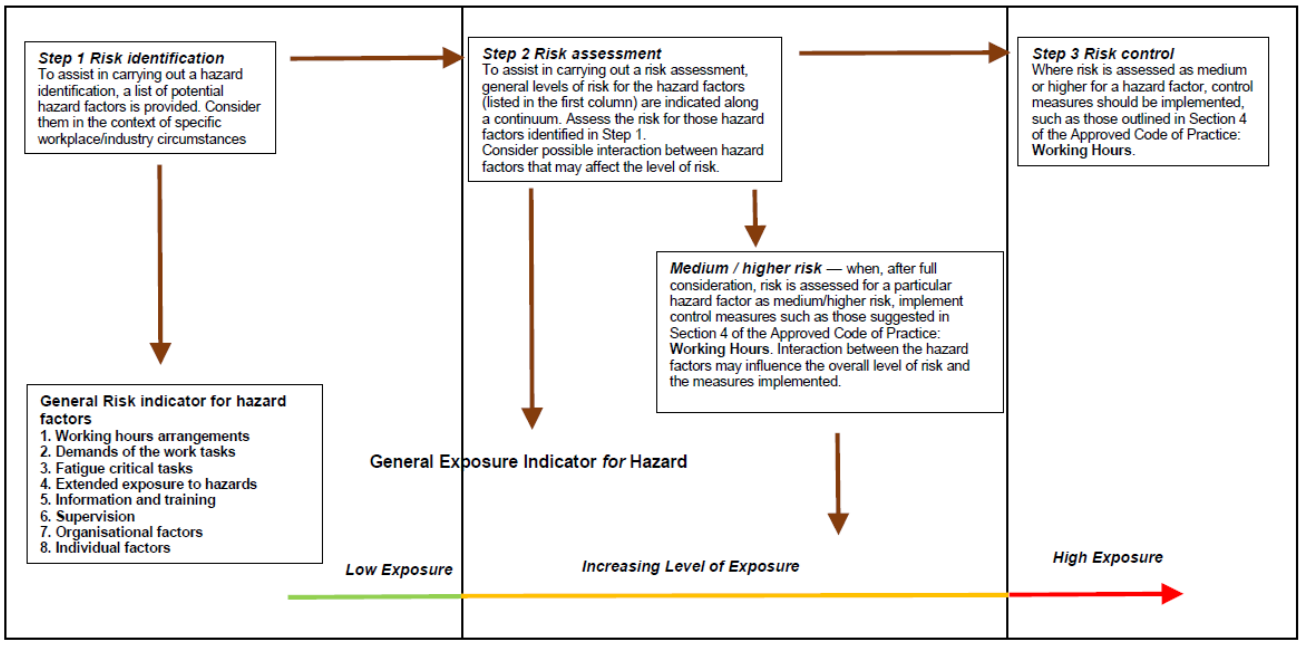


Figure 6: - The risk management matrix

(EasyOHS, n.d.)

This resulted in a basic static feedback model. The practical application of this model would be to estimate, monitor and provide quantitative information that can aid the miners and mining administrators' or policy makers in decision making; thus reducing the impact of ONIHL in the mine. Additionally, the model forms part of early intervention and management of ONIHL in the workplace. The input to this model is the occupational noise exposure naïve person (person who has not been exposed to excessive occupational noise that has caused permanent threshold shift). The occupational noise exposure is the disturbance to the system. The estimated ONIHL is the output. These systems may therefore be defined as a feedback based Single Input Single Output (SISO) nonlinear stochastic system. Shown in figure 7 below, is the feedback-based model that is developed from the noise management matrix in figure 2 above. The ISO:1999 international standard statistical equations are used for the model (ISO 1999: 2013).

Overall system diagram for a feedback based model for NIHL monitoring

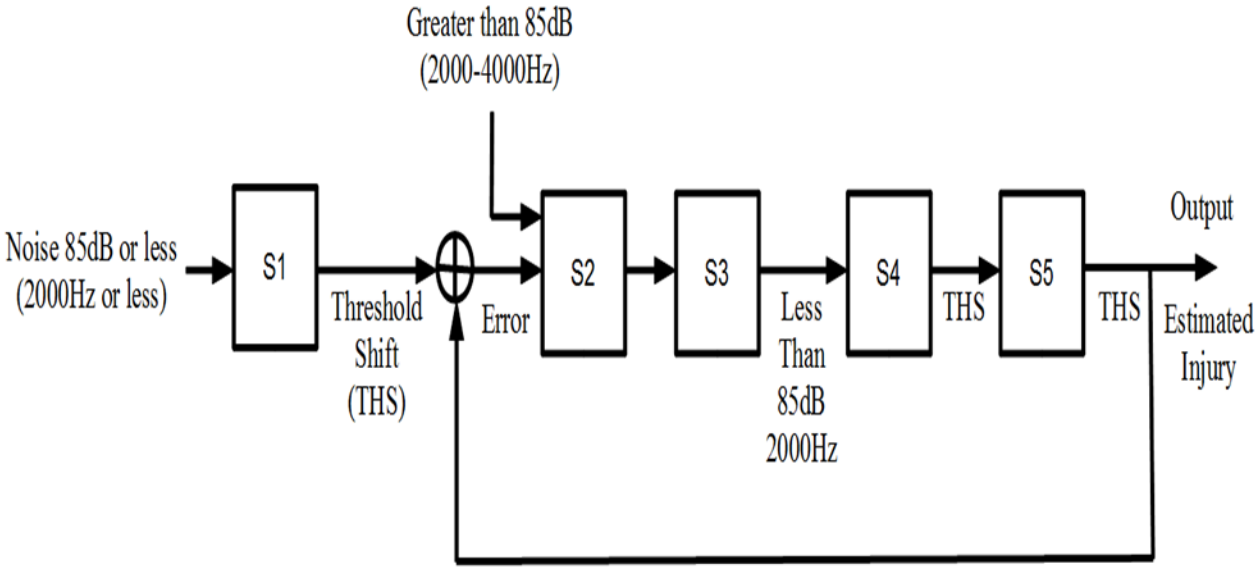


Figure 7: - Overall model diagram for a feedback-based model for ONIHL monitoring

8.5 Model description

8.5.1 Threshold shift for an individual not exposed to occupational noise

In figure 7, S1 represents the threshold shift of an individual who has not been exposed to occupational noise. Equation 1 is used to determine the effects of age on the hearing ability of this individual. The input to this system is noise exposure which is less than 85dB at 2000 Hz, at this level of exposure and frequency in the absence of any other factors; for instance exposure to a sudden explosion (Burns, Robinson, & Great Britain, 1970), then the only loss that would occur is hearing loss due to presbycusis. The output to this system is the hearing threshold shift. The hearing threshold level associated with age (HTLA) (ISO 1999: 2013) is calculated as shown in equation 2. The formulae applicable for the hearing threshold, H, as a function of age Y (years), for the various ranges of the percentage, Q, having hearing threshold levels exceeding the value H_Q are: The coefficient of a are shown in table IV

For Q = 50%

$H_{md,\,Y} = a(Y-18)^2 + H_{md;18}$.....(1)

For $5\% \leq Q < 50\%$

$H_Q = H_{md,Y} + KS_u$.....(2)

For $50\% < Q \leq 95\%$

$H_Q = H_{md,Y} - KS_1$.....(3)

8-1: - Table IV: Coefficient of "a" values

Frequency (Hz)	a (dB/year^2) Male	A (dB/year^2) Females
125	0.0030	0.0030
250	0.0030	0.0030
500	0.0035	0.0035
1000	0.0040	0.0040
1500	0.0055	0.0050
2000	0.0070	0.0060
3000	0.155	0.0075
4000	0.0160	0.0090
6000	0.0180	0.0120
8000	0.0220	0.0150

Where

S_u is the standard deviation of the upper half of the distribution

S_1 is the standard deviation of the lower half of the distribution

$H_{md,\ 18,}$ is the median value of the hearing threshold of ontologically normal persons of the same sex aged 18 years, which for practical purposes is taken as zero, as specified in the ISO 389 series. Hence, H_Q is the hearing threshold level associated with age.

The values for the co-efficient "a" and the multiplier are presented in Tables I and II. (ISO 1999: 2013).

8-2: Table I: U, V, L0

Frequency (Hz)	U	v	L_0
500	- 0.033	0.110	93
1000	- 0.020	0.070	89
2000	- 0.045	0.066	80
3000	0.012	0.037	77
4000	0.025	0.025	75
6000	0.019	0.024	77

8-3: - Table II: K values

Q	K	Q	K
5	1.645	50	0
10	1.282	95	1.645
15	1.036	90	1.282
20	0.842	85	1.036
25	0.675	80	0.842
30	0.524	75	0.675
35	0.385	70	0.524
40	0.253	65	0.385
45	0.126	60	0.253
		55	0.126

$$S_u = b_u + 0.445\, H_{md,\,Y} \quad \text{.....(4)}$$

$$S_1 = b_1 + 0.356\, H_{md,y} \quad \text{.....(5)}$$

The values of b_1 and b_2 are listed in Table III and Table V.

8-4: - Table III: Xu, Yu, Xl, and Yl

Frequency	X_u	Y_u	X_l	Y_l
500	0.044	0.016	0.033	0.002
1000	0.022	0.016	0.020	0.000
2000	0.031	0.016	0.016	0.000
3000	0.007	- 0.002	0.029	- 0.010
4000	0.005	0.009	0.016	- 0.002
6000	0.013	0.008	0.028	- 0.007

8-5: - Table V: bu and bl values

Frequency (Hz)	b_u (dB)Males	b_u (dB) Female	b_l (dB) Males	B_l(dB) Females
125	7.23	6.67	5.78	5.34
250	6.67	6.12	5.34	4.89
500	6.12	6.12	4.89	4.89
1000	6.12	6.12	4.89	4.89
1500	6.67	6.67	5.34	5.33
2000	7.23	6.67	5.78	5.34
3000	7.78	7.23	6.23	5.78
4000	8.34	7.78	6.67	6.23
6000	9.45	8.90	7.56	7.12
8000	10.56	10.56	8.45	8.45

8.5.2 Policy and Intervention

S2 is the system that represents the mandatory code of conduct imposed in a mine for both surface and underground employees and anyone on site (Mine Health and Safety Inspectorate, 2003). S2 is simplified by lumping the policies and the intervention together. Depending on the policy implemented by the mine, occupation noise is attenuated or increased. The system is therefore represented with an equation used by manufacturers in the industry in design of noise reduction protective gear (Bannon & Kaputa, 2015), shown by equation 6.

$d = 20 \text{Log}_{10} (1 - C)$……. (6)

8.5.3 Sensors

S3 is the sensing unit of the model. The sensor used in this unit is the NIOSH Sound Level Meter mobile application tool (National Institute for Occupational Safety and Health, n.d). This sensor is used to measure sound levels in the mine and it outputs the noise intensity and the frequency. The subunits within the subsystem constitute a sound level meter. The transfer function of this unit is used to provide information on the behaviour of the subsystem.

8.5.4 Threshold shift for an individual exposed to occupational noise

S4 is defined by equation 7 below and it represents an individual who has been exposed to occupational noise in the presence of presbycusis.

$$H' = H + N - \frac{HXN}{120} \quad \text{.....} \quad (7)$$

H' = Hearing threshold level, in decibels, associated with age and noise (HTLAN)

H = Hearing threshold level, expressed in decibels, associated with age (HTLA)

N = Actual or potential noise induced permanent threshold shift (NIPTS), expressed in decibels.

N is calculated using the following equations;

$N_{50}\ [uv\lg(t/t_0)]\left(L_{\mathrm{EX,8h}}\right)^2$ ……(8)

$N_{50,t<10} = N_{50,t=10}$……..……(9)

$L_{ex,\ 8h}$ = is the noise exposure level normalized to a nominal 8 h working day, expressed in decibels

L_o = is the sound pressure level, defined as a function of frequency, expressed in decibels, below which the effect on hearing is negligible

t = is the exposure duration, expressed in years

t_o = 1 year

u and v are given as a function of frequency.

This formula applies to $L_{ex,\ 8h}$ greater than L_o. In cases where $L_{ex,\ 8h}$ is less than L_o, it shall be deemed equal to L_o so that N_{50} is zero

8.5.5 Check up

S5 represents the check subsystem. This can be daily, weekly or monthly monitoring of the hearing threshold shifts. For annual and biannual check-ups, an audiogram is used to establish if a temporary threshold shift has resulted into permanent threshold shift thus damage to hearing resulting in ONIHL. Temporal check-up can be performed on a weekly or monthly basis to establish the integrity of the inner ear hair cells in the cochlear.

8.6 Application of the feedback model: Preliminary Results

To demonstrate the use of the feedback model, the following scenario was created. Six mine workers comprising of 3 females and 3 males who started employment at the age of 50, 40 and

25yrs are used as case studies (Figures 5-10). They work in a deep mine with the highest noise intensity of 107 dB at a frequency of 4000 HZ. The results show the pattern of threshold shift if the workers were without hearing protection for 15 years. The existing baseline of the mineworkers is ignored and hence all of them are assumed to have perfect hearing with no previous exposure to occupational noise.

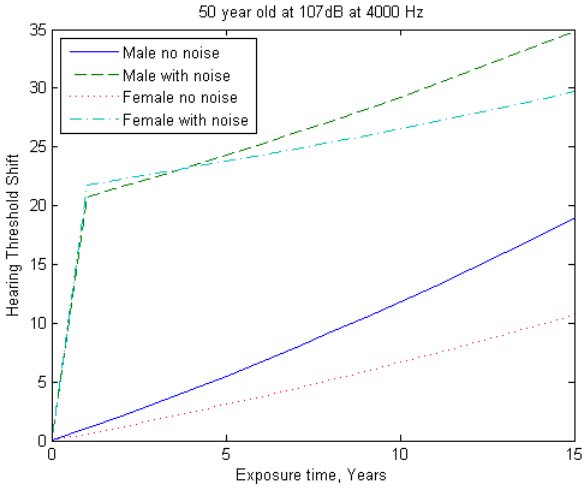


Figure 8: - 50 year old, mine worker's threshold shift without hearing protection

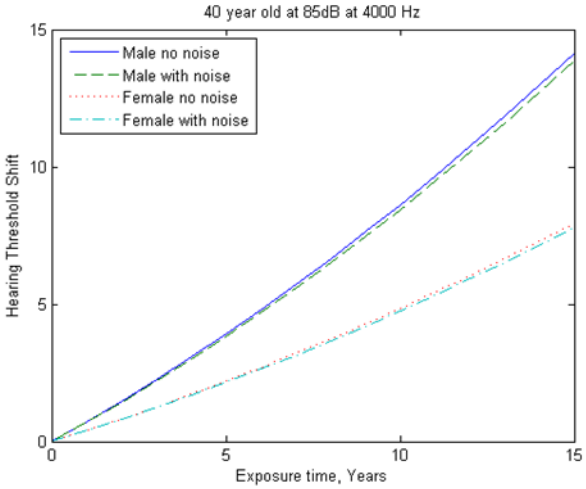


Figure 9: - 50 year old mine worker's threshold shift with hearing protection

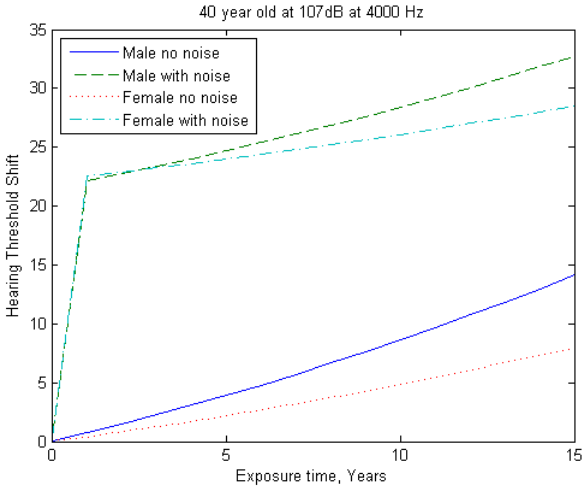


Figure 10: - 40 year old mine worker's threshold shift without protection

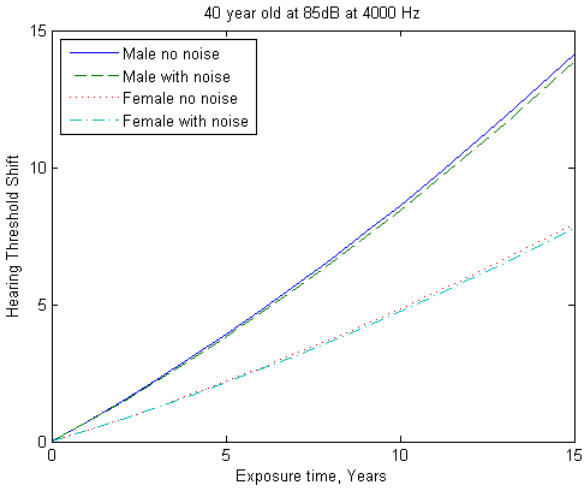


Figure 11: - 40 year old mine worker's threshold shift with protection

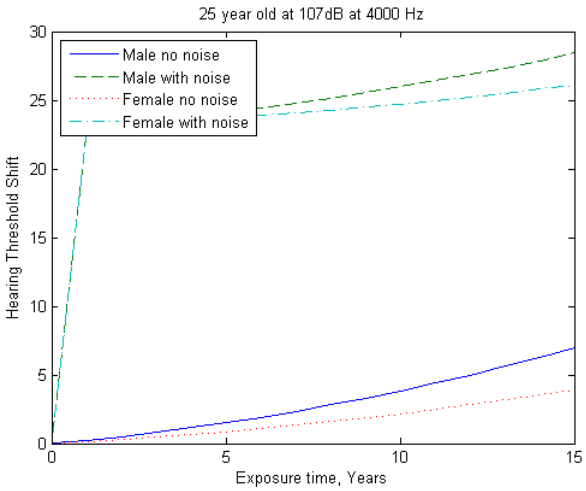


Figure 12: - 25 year old mine worker's threshold shift without protection

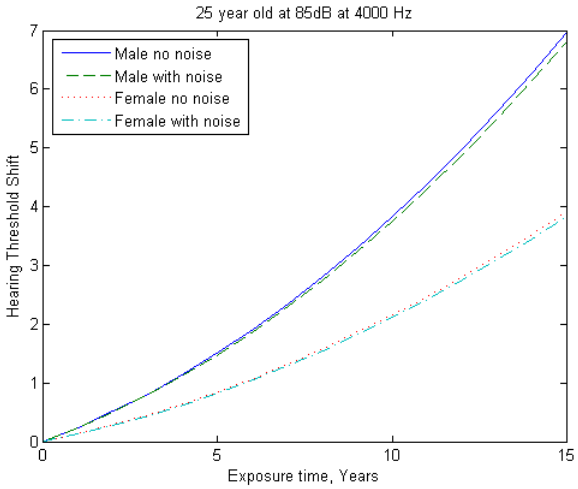


Figure 13: - 25 year old mine worker's threshold shift with protection

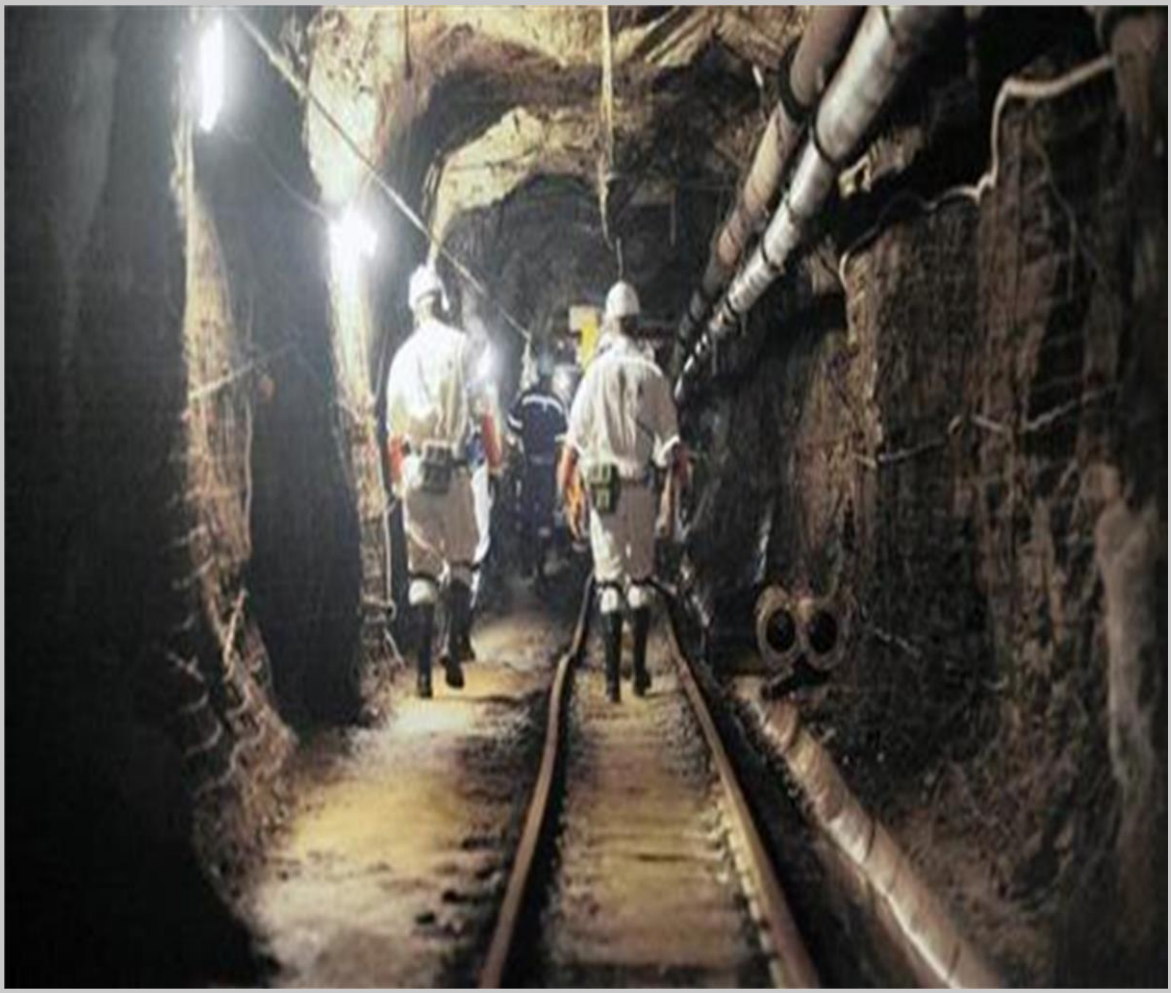
From the graphs, it is evident that if left unprotected, all mineworkers irrespective of their age, in less than 10 years, will have experienced a threshold shift of more than 25 dB from their given baseline. The designed system currently offers a predictive model to the mine administrators who should now take measures to monitor the mineworkers frequently to ensure that the threshold does not shift by more than 25 dBs as stipulated by the mine health and safety council 2014 milestones.

8.7 Conclusion and Recommendations

Successful elimination of ONIHL is the goal of any HCP. Efforts towards enhancing strategies to achieve this goal should be increased. Research into HCPs and their effectiveness with tangible recommendations on how to manage this occupational health risk should be prioritized. The model introduced in this paper is aimed at this. This proposed model should be interpreted taking cognisance of the following three identified limitations, which will be addressed in the subsequent planned paper:

- Firstly, the presented model is a static model and currently excludes the dynamic aspects. Future plans will include the dynamic aspects currently excluded thus allowing the mine administrators the ability to access real time hearing status of the workers while at work.
- Secondly, the current model does not include a controller. Future plans will include design of linear and nonlinear controllers for the system, thus allowing for interpretation of policies using control law.
- Lastly, model validation with real audiological patient data has not been performed. Therefore, the model will be validated using real data from the mines in the planned subsequent paper.

CHAPTER 9. SYNTHESIS OF THE FINDINGS



Every mine worker returning from work unharmed every day *(MHSC, 2014)*

9.1 Introduction

This chapter summarises and integrates the papers presented in chapters three eight. The overall aims of the study are reviewed, followed by a discussion of the integration of findings of the six papers included in this thesis. Contributions of the research to the body of knowledge on occupational audiology, particularly in relation to the management of excessive noise in the workplace are also discussed. Additionally, this study's limitations are identified and proposed future studies are suggested.

9.2 Aim of the study

The purpose of the current study was to explore the management of ONIHL in South African large-scale mines – from policy formulation to implementation and monitoring. The objectives of this study included reviewing current regulations, Acts, and policies regarding occupational noise-induced hearing loss in the South African mines. Additionally, this study sought to establish the extent the above policies were observed, and/or implemented in HCPs in South African mines. Furthermore, it explored factors influencing implementation of HCPs within this context. Lastly, it explored the role of audiologists in HCP in the mining sector.

9.3 Main findings

"One of greatest pitfalls in conducting research successfully is the inability to obtain access to the research field" (Johl & Renganathan, 2010, p. 42). Consequently, researchers spend a considerable amount of valuable time gaining access to research sites. This is particularly the case when the phenomenon under investigation is sensitive or requires in-depth and contextual knowledge of the

possible participants (Johl & Renganathan, 2010; Okumus, Altinay, & Roper, 2007; Shenton & Hayter, 2004). Such was the case in the current study.

The researcher was unable to gain access to 14 mines identified as suitable for this study. According to Kondowe and Booyens (2014, p. 146) "Listening to lecturers and reading text books, students may think planning a research project, gaining access to a site and finding willing participants is a straightforward process. On the ground, however, they are confronted with a much messier situation". In such circumstances, students are forced to develop a range of research skills and develop new attitudes in dealing with practical realities and unforeseen challenges such as gaining access is critical (Kondowe & Booyens, 2014). In the case of the current study, during the conceptual and proposal phase, different methodology and research processes were envisaged. However, after 18 months of not obtaining access into the mines, dealing with unforeseen challenges, frustrating realities and developing new attitudes, as mentioned by Kondowe and Booyens (2014), the methodology of this study was significantly modified due to failure in gaining access to the mines.

Although the objectives for this study remained the same, the methodology, particularly in terms of collecting data, was drastically changed. The initial study was premised on a convergent parallel research design, a mixed method approach based on a systematic means of collecting, analysing, and combining both qualitative and quantitative data in a single study or a series of studies (Creswell, 2012). This approach consists of merging, integrating, linking or embedding two threads of data to better understand and report a research problem (Cresswell & Plano Clark, 2011). With this approach, both quantitative and qualitative data are collected simultaneously, analysed separately and then results of both sets are compared to determine whether or not the results support or contradict each other. Collecting both quantitative and qualitative data

simultaneously, and analysing them separately was strategic because the objective was to allow for triangulation of the findings (Cresswell & Plano Clark, 2011). Data were to be collected through:

- Questionnaires with the Stakeholders – state, labour and employer representatives:
    - The questionnaire sought to understand what informed the need for noise regulations to be implemented in the mines. As well, it was imperative to understand the objectives and outcomes anticipated when the regulation was implemented. Furthermore, it was crucial to establish what monitoring and evaluation protocols were in place when these regulations were implemented. Lastly, to ascertain the factors influencing the success or failure of meeting MHSC milestones.
- Retrospective archival review of audiograms:
    - The first target of the 2003 MHSC milestone aimed to eliminate hearing deterioration greater than 10% in individuals exposed to excessive occupational noise by December 2008. In line with this target, a retrospective reviewing of audiograms from 2003 to 2016 was to be conducted. The aim was to determine if there were any differences or changes in terms of degree of hearing loss since implementation of the new regulations. As well, this study sought to determine if the rate of compensation claims had increased, decreased, or stayed the same.
- Interviews with the managers and ground workers at the large-scale gold mines:
    - These aimed to obtain their views on the regulations and policies established in 2003. Furthermore, this study explored factors influencing implementation and success of HCPs currently practiced at the mines. Lastly, the responsibility each party – managers and ground workers – take in ensuring MHSC milestones are met.

- Observations: at large scale gold mines
    - To document actual practices of workers in relation to noise prevention and control while at work. This activity included observing noise warning signs when approaching noisy areas; use of hearing protection devices when using noisy machinery or working in noisy areas.
- Sound Level Measurements:
    - To ascertain if the mines are meeting the MHSC second milestone of reducing intensity of noise emitted by machines.

The combination of the above data collection tools would have enabled the researcher to confirm data obtained from the interviews and questionnaires using audiograms, observations and noise measurements.

According to Johl and Renganathan (2010), many academics often face numerous obstacles in attempting to gain access to various organisations where they would like to carry out their research. These obstacles are driven by several concerns: value cost of time, skepticism regarding the role of outside researcher, and academics' failure to provide thorough, informative answers relating to the value of the study. These are discussed below.

Easterby-Smith, Thorpe, and Lowe (2002) caution, when attempting to get access to large profit organisations, there may be challenging roadblocks in, generally, managers above all value cost of time. Therefore, for such cases questionnaires are far more feasible than interviews and observations and findings of the current study support this view.

Out of the five activities proposed for data collection for this study, only the stakeholders agreed to participate. Initially, these stakeholders were told data would be collected through questionnaires. However, it turned out these were collected through in-depth interviews. This was

due to the researcher's realisation other methods of data collection may not materialise. Therefore, the questionnaires were converted into in-depth interview guides and the participants agreed to continue participating.

Laurilla (1997) suggests organisations are usually skeptical regarding the role of outsiders. Hence, they may not value academic studies. This was a reality in the current study. Current findings revealed organisations are guarded when it comes to the sharing information any aspect of their operations. As presented in chapter 5 of this thesis, some participants requested pre-access to the interview questions and a right to approve the final report of the study. These findings confirm the sentiments by Laurilla (1997) as some participants showed some level of unease towards the researcher. Consequently, they appeared cautious about revealing any information that might be deemed damaging to the individual and/or the organisation concerned. This occurred despite assurances of confidentiality and anonymity in reporting as dictated by the ethics approval process.

Organisations may restrict access due to the academic's failure to provide answers about what, how, and why they are conducting certain studies, and whether the proposed study would yield any direct value to the organisation itself (Coleman, 1996). In the current study, the researcher faced the challenge of having to prove direct value to mine administrators. Potential mine representatives asked about the value of the study for their organisation. One particular representative asked: "You will get your PhD and what would we get in return"? The researcher then presented the research proposal of the study specifically highlighting the benefits to the mine (appendix K). Following the presentation, management representatives agreed the study had merit and was beneficial for their organisation. However, they wanted to be actively involved throughout

the study. This active involvement included the following conditions, which the researcher declined:

- The study to be exclusively conducted at this specific mine
- To fund the study
- To have access and rights to all collected and analysed data
- To have the prerogative to decide what data to be included and excluded in the final report

Consequently, the researcher was not given access to this specific mine.

Johl and Renganathan (2010) and Feldman, Bell, and Berger (2003) lamented a paucity of studies conducted on the challenges of gaining access into research sites. Their observations are true judging by the few studies of this sort. A number of reasons may be attributed to this situation. For instance, in the current study, when access into the mines was denied, the researcher saw an opportunity to carefully document and publish those instances. However, the researcher did face challenges in getting the manuscript on exploring the ease of accessing the South African mining industry for research purposes published. The manuscript was rejected twice by journals. See chapter 5. One journal responded thusly:

> Thank you for submitting "Research into Occupational Noise induced Hearing Loss in South African large scale mines: Access Denied?" to (Journal name removed). Although your study was well conducted, I am not considering it for publication as a Technical article in the (Journal name removed). I believe it is well appreciated that the managers of private and public organisations resist independent investigations of health and safety hazards faced by their employees. The findings can make them accurately appear derelict in their responsibilities, can support actions by employees for compensation, and might even

pressure regulatory agencies to do their jobs. Such outcomes are simply ghastly from a management point of view.

Such responses from journals do enough to deter researchers from publishing their work, which ultimately leads to dearth of studies reporting these concerns in gaining access into research sites. The obvious implications of this challenge is a lack of contextually relevant and objective evidence base to guide interventions within this sector.

Consequently, with regard to gaining access into research sites, Gummesson (2000) concludes the hurdles in accessing research sites are often neglected or seen as merely tactical issues. In complementing this statement, although anecdotal, one mine representative stated due to the active class action on silicosis and TB in South Africa, mines are extremely cautious of letting objective researchers have access to data. This representative continued to say: "it all started off with people asking questions about silicosis and the next thing there was a class action. How do we know the same won't happen with noise"? Based on this, it can be surmised denying researchers access into the mines at this stage is a tactical strategy from the mines to ensure they do not end up with another class action lawsuit in their hands. Therefore, a hard and valuable lesson can be learned from this study, with regard to gaining access to research sites. It echoes the statement by Van Maanen and Klob (1985) accessing research sites is crucial and should not be taken lightly.

Based on the above discussion, findings of the current study indicate the inability to access mines for data collection was the most significant finding of this study. This raised further significant implications, not just for the researcher and the study itself, but for the mining industry as well. Current findings confirm this to be true to the concerns of the South African Mining Lekgotla chairperson (Booyens, 2013), the mining industry is not obtaining desired outcomes.

Restricted access into mines places critical implications for the mining industry in that it raises questions regarding the dedication and commitment of the mining industry to address ONIHL. According to Brown, Hitchcock, and Willard (1994); and Peyman, Mostafa, and Mohammad (2005) failure of improvement programmes can be attributed to a lack of commitment from top management.

In this study, top management refers to the Department of Mineral Resources (DMR) and the Chamber of Mines (CoM). The DMR is responsible for overseeing the mining industry while the CoM is the industry's employer organisation that supports and promote employer's interests by providing strategic support and advisory input. Arguably, these two organisations are overseers of the mining industry. However, according to representatives from MHSC, specifically, the CoM and DMR, mining companies have the latitude to practice organisational autonomy. Organisational autonomy is broadly defined as the degree to which individuals/organisations have freedom, independence and discretion in scheduling work and determining how to carry out that work (Burcharth, Knudsen, & Søndergaard, 2017). This was revealed when the researcher approached the CoM regarding access to the mines. The representative told the researcher: "…as the Chamber, we can only recommend or advise the mines on what [to] do, but we cannot dictate or force them to do anything". Similarly, when discussing the scarcity of audiologists in the mining sector with a representative from the DMR, the representative stated they appreciate the need for more audiologists, however, they cannot dictate to the mines whom they can hire.

These findings highlight the challenges mining regulators experience regarding enforcing certain legislations in the mining sector. The companies themselves still have organisational autonomy and the mine regulators do not have a mandate to overstep their boundaries to allow the mines to practice managerial autonomy. This may suggest the Chamber of Mines may be

committed to eradicating ONIHL in the mining sector as stated by the Mining Lekgotla chairperson (Booyens, 2013). However, they can only make recommendations to the individual mining companies. Nevertheless, this raises challenges if ONIHL is deemed an occupational health and safety priority. How does the mining industry envisage addressing this concern if the regulators do not have the mandate to enforce certain instructions such as allowing researches to access the mines for data collection? It is intriguing that on the one hand, the mining industry realises the need to conduct comprehensive noise-control programmes while on the other, they are not providing researchers with appropriate material to conduct such studies. Therefore, the mining industry needs to deliberate on these issues. In reality, the mining industry itself may be a barrier to attaining MHSC milestones related to occupational health.

In reviewing policies, regulations and Acts on ONIHL in the mining sector, this study concurs with a study conducted by Edwards et al. (2015). Although, Edwards's study was concerned with awareness training programmes of mineworkers, their findings revealed the investigated mines lacked a solid and consolidated theoretical basis for their awareness training programmes.

In this study, a similar finding surfaced. Stakeholders interviewed in the current study reported one of the major challenges they experienced with the formulation and implementation of the 2003 MHSC milestones mainly centred on a lack of clearly defined action plans, as well as lack of collaboration from all stakeholders. According to Byrne (2005), the first step mines should consider before implementing a programme is to address administrative issues where company regulations/policies are clarified as well as the individuals' responsibilities/roles are identified and enforced. In addressing administrative issues, stakeholders should identify and define their organisation's theoretical basis and action plans to succeed in their interventions. For campaigns

to be effective, proper planning with clear objectives and desired outcomes is required in order to enhance the success of the programmes (U.S. Department of Health and Human Services, 2011).

Furthermore, the National Center for Injury Prevention and Control (2011) suggests the success of any policy or regulation heavily relies on the sound knowledge and involvement of policymakers and stakeholders involved from conception to implementation, monitoring and evaluation. In this study, there was a lack of collaboration and buy-in from all stakeholders involved. This is evidenced by the responses obtained from the stakeholders presented in chapter 3. This lack of support from stakeholders may lead to challenges to successfully implement HCPs, thereby sabotaging the entire mission (U.S. Department of Health and Human Services, 2011).

Furthermore, in this study, access to company specific policies, regulations and Acts was not possible because access was restricted to company members or staff. Therefore, document analysis was conducted via policies on occupational health and safety available online. Most of these documents were from the MHSC and Department of Mineral Resources. In interrogating these documents, particularly the 2003 and 2014 MHSC milestones on the elimination of ONIHL in the mining sector, there were shortcoming in the structuring and framing these milestones as presented in chapter 7. These shortcomings included the fact that the milestones only focus on two aspects of hearing conservation-hearing deterioration and noise source; the sequencing of these milestones and the increase in the timeframe of reducing noise at the source- from 5 to 8 years.

Furthermore, findings from the document analysis corroborate conclusions of the systematic review of literature on management of ONIHL in Africa as presented in chapter 4. The systematic review indicated most studies on the use of HCPs to manage ONIHL in the mining sector are conducted in a piecemeal fashion, where specific pillars are targeted in isolation.

Therefore, in reviewing these policies on ONIHL, it was discovered the MHSC milestones focused on noise deterioration and noise source as the areas of priority and focus.

Targeting these two aspects is commendable, particularly when one considers according to the National Institute for Occupational Safety and Health (2016), engineering controls are the first line of defense against ONIHL. However, the manner in which these targets are articulated seems to suggest the focus is on monitoring threshold shifts of individuals instead of investing in managing the noise at the source by purchasing quieter machinery (National Institute for Occupational Safety and Health, 2016; Suter, 2012). To be fair, in the interviews conducted with various stakeholders, see chapter 3, and from the findings of systematic review in chapter 4, there was an indication the South African mining industry is moving towards buying less noisy equipment. For instance, Burger et al. (2004) designed and developed a low noise rock drill for use in the mining industry. Based on interviews with stakeholders, buying quieter machinery was hailed as the best practice and innovation. However, there also were concerns associated with the cost of acquiring new and quieter machines. In response to concerns, questions regarding the cost of the health and well-being of the workers were also brought to the fore.

If the mining industry is concerned with the wellbeing of its employees and committed to eliminating ONIHL, engineering controls should be the first line of defense against exposure to loud noise. According to Byrne (2005), if engineering controls are implemented correctly, there may be no need for other controls such as the use of personal hearing protection devices.

Furthermore, costs related to hearing monitoring in the form of regular hearing tests as well as costs related to compensation may also be completely eliminated – over and above the elimination of disability for the employees (Byrne, 2005). Bruce (2007, p. 33) asserts implementation of engineering controls has benefits which include “permanence, effectiveness

with or without worker/supervision compliance, less absenteeism, easier communication, lower worker compensation costs, and reduced legal costs". These benefits should be a strong incentive for the mines to invest in buying quieter equipment. (Bruce, 2007). Thee researcher believes adopting a position where 'buying-quiet' – purchasing quieter machinery – is structured as a long-term investment. The benefits may far outweigh the perceived costs associated with engineering controls, particularly of buying quiet being perceived as arduous and costly. Based on participants' responses, it is encouraging to see the South African mining industry being committed to prioritising and investing in "buying-quiet".

It is important to emphasise all pillars of the HCPs are equally important. However, pillars such as engineering controls, administrative controls and education are critical in any HCP. This position is based on the assertions by Byrne (2005) who posits: if engineering controls [and education – researcher emphasis] are implemented correctly, and employees [are educated adequately educated about the effects of exposure to excessive noise in the workplace – researcher emphasis], there may be no need for other controls such as the use of personal hearing protection devices. Currently in South Africa, there is a heavy reliance on the use of HPDs as the first line of defense, as presented in chapter 4. This is despite the guidelines from the Department of Mineral Resources DME (2003) stating HPDs are the last line of defense should engineering and administrative controls fail.

According to Hugo, as cited by Heath (1982, p. 6) "no cause can succeed without first making education its ally". This claim resonates well in this study, as the researcher concurs that one of the most important components of an effective HCP is the education and motivation of workers and management (American Speech-Language-Hearing Association, 2004a). The South African mining industry needs to prioritise education and motivation of mineworkers in order to

minimise hearing loss in the mines. Education and motivation create opportunities for both management and employees to discuss and agree on commitments, communication lines and cooperation (Byrne, 2005). Training and education can avail opportunities to explain various pertinent topics such as the effects of noise on hearing, as well as the purpose and value of wearing HPDs. Furthermore, during training, advantages and disadvantages of hearing protectors presently offered can be discussed in detail, with an opportunity for highlighting the miners' and the operators' responsibilities in maintaining noise controls (Byrne, 2005).

If individuals understand the reasons and the benefits of a HCP, they are more likely to participate, especially if training addresses the specific needs of individuals exposed to excessive noise. Additionally, training may be more effective if conducted continuously and in small groups. At the very least, training should occur at the time of annual hearing tests to stress upon workers the importance of using HPDs (Byrne, 2005).

Participants in this study were asked about the training and education of the mineworkers on ONIHL and its effects. Findings revealed mineworkers are trained on the importance of protecting their hearing against excessive noise in the workplace. Participants shared successes as evidenced by the change in the workers' attitudes with regard to ONIHL. However, when the participants were asked to elaborate on how workers are trained, findings indicated the stakeholders were not entirely informed on the subject. Reasons such as language barriers, limited scope of practice and bonus incentives on the worker's part were cited as factors negatively contributing to poor training of workers. This was presented in chapter 5.

Findings of the current study revealed that stakeholders are not informed regarding mineworkers' education and training on ONIHL. This is concerning. As mentioned earlier, Byrne (2005) stresses the importance of addressing administrative issues such as company regulations as

well as individual's responsibilities before implementing HCPs. Based on the responses from participants it is not clear who is responsible for training and educating mineworkers on ONIHL.

Internationally, audiologists are identified as professionals responsible for managing ONIHL (American Academy of Audiology, 2003). The scope of practice for audiologists includes, among other responsibilities, the prescription of and counselling for the use of hearing protection as well as education and training of employees (American Academy of Audiology, 2003). However, at present in South Africa, there are no guidelines or position statements defining the holistic role of audiologists and the management of ONIHL.

Currently, the HPCSA (the body that regulates audiologists in South Africa is silent on the role of audiologists in the management of ONIHL. Only two guidelines were identified on the role of audiologists in managing excessive noise in the workplace. However, these guidelines limited this role to audiometric surveillance and compensation of hearing loss in the mining sector (De Koker, n.d.; de W Oosthuizen, 2006). Consequently, there are just a few audiologists employed in the mining sector, as mines prefer services of audiometrists who are considered more cost effective, as presented in chapter 6.

Findings presented on chapter 6 corroborated the concerns by Edwards et al. (2015). Mines have few qualified professionals who possess knowledge and skills to teach adults workers to achieve health promotion and behaviour change. Therefore, current findings highlight the important role of audiologists in actively participating in educating and training mineworkers on the impact of ONIHL on their health. These conclusions also complement the findings by Mutara and Mutanana (2015) who, after analyzing a HCP at a mine in Zimbabwe, concluded the operation should enlist the services of a resident audiologist to assist non-compliant employees. These findings by Mutara and Mutanana (2015) attest to the role of audiologists in the management of

ONIHL. In exploring the role of audiologists for the current study, findings revealed challenges such as scope-context misalignment, juniorisation of audiologists, poor understanding of the role of audiologists, as well as limited training in occupational audiology for audiologists currently in the field. These results have implications for both the mining sector as well as the audiology profession in South Africa.

Regarding linguistic diversity as a barrier contributing to poor training of the mineworkers, responses from participants are consistent with results reported by Edwards et al. (2015). Languages used for training mineworkers were not reflective of the cultural and linguistic diversity of the South African population. According to former South African president, Nelson Mandela, "If you talk to a man in a language he understands, it goes to his head. If you talk to him in his language that goes to his heart" (Laka, 2014, p. not provided). This quote rings true in the South African context where language seems to be a barrier in achieving desired outcomes in the training of workers. South Africa is a multicultural and multilingual country with 12 official languages, including South African Sign Language (Brenzinger, 2017). Using English as a chosen mode of communication as indicated in the study by Edwards et al. (2015) excludes workers who may not be proficient in English.

In the 2011 Census, results indicated Zulu is the most spoken language with English ranking at number four (South African Statistics, 2016). This creates a challenge to training workers on the importance of hearing conservation. If training is conducted in English or any other unfamiliar language the message is not going to be understood. Furthermore, South Africa's major contribution to mineral wealth works like a financial beacon. Workers from neighbouring countries immigrate to South Africa to seek better job opportunities in the mining industry (van Averbeke, 2003). This immigration has facilitated diversity of the mining workforce both linguistically and

culturally. Consequently, this diversity has given birth to a pidgin language known as Fanakalo (Pewa, 2001), which was and continues to be informally used in some mines for communication.

However, according to Creamer Media (2008) some mines introduced the 'Oral Language Development Programme' which saw Fanakalo formally phased out in the mines. English and a dominant vernacular language were formally introduced as mediums of communication in the mines (Creamer Media, 2008). Reportedly, the decision to phase out Fanakalo was mainly due to the adverse effects on communication and safety concerns (Creamer Media, 2008). For example, at the Anglo platinum mine, reportedly, all employees, supervisors and management underwent training over a period of three years to learn English as well as the relevant dominant local language. Following the training, 6000 miners from Anglo platinum who participated in this study reported the language policy had improved safety issues in the work place (Creamer Media, 2008). With this background on language in the mining sector, it is interesting to confirm language is still an issue as indicated in the current study. Participants still highlighted language as a momentous factor in communicating with the mineworkers.

Another concern emphasised by Edwards et al. (2015) is material content used to train workers was the same as used for managers and other higher levels of workers. To address concerns regarding the material used in the mining sector, information presented to workers must be matched to the worker's levels of understanding. This may be done by utilising a range of modalities such as verbal, visual and printed material to enhance learning and improve awareness while observing literacy, cultural, and linguistic relevance.

According to Zuhlke and Engel (2013) if appropriate communication skills are used, even complex concepts can be understood. For instance, in chapter 6, one audiologist emphasised that the ear and hearing are abstract concepts for mineworkers. Therefore, paying full attention to the

mode of presentation should assist in explaining even the most complex concepts as suggested by Zuhlke and Engel (2013). Additionally, according to Clayton (2010) it is known physicians' explanations and the level of patients' understanding significantly affect treatment adherence, treatment outcome, and patient satisfaction. The same argument applies to occupational health professionals such as audiologists. If trainers explain concepts at the level of mineworker's understanding, workers will have deeper knowledge and awareness of the consequences of excessive exposure to noise in the workplace. Therefore, they will be more likely to practice behaviour change.

Another aspect emerged while exploring the views of stakeholders regarding the formulation, implementation and monitoring of HCPs. This was the exclusion of audiologists and employees exposed to excessive noise in the mining industry. In chapter 5 for example, audiologists lamented their exclusion from processes of implementing HCPs, particularly in the formulation of policies. The practice of excluding audiologists in the management of ONIHL undoubtedly has had negative consequences for the mining industry.

As detailed in chapters 5 and 6, practical management of ONIHL forms only a part of an audiologist's scope of practice. According to the American Academy of Audiology (2003), audiologists should be the principal advocates for and supervisors of HCP. Audiologists design, implement, and coordinate occupational and community hearing loss prevention programs. This includes identification and amelioration of noise-hazardous conditions, identification of hearing loss, recommendation and counselling for use of hearing protection, as well as employee education. Their job function also includes training and supervision of non-audiologists performing monitoring audiometry in the occupational setting (American Academy of Audiology,

2003). This is cited in the American Academy of Audiologist Position Statement (American Academy of Audiology, 1997).

Currently in South Africa, audiologists have a limited role in the management of ONIHL in the mining sector as detailed by De Koker (n.d.) and de W Oosthuizen (2006). Furthermore, audiologists fall into the same category as audiometrists, occupational hygienists and occupational medical practitioners. Therefore, as long as they are registered with the Health Professionals Council of South Africa (HPCSA) and/or the South African Society of Occupational Health Nursing Practitioners (SASOHN) (de W Oosthuizen, 2006), they can practice.

This is highly concerning; when considering the mining industry prefers the services of audiometrists, who do not have the training, skills and knowledge in the management of ONIHL. Audiologists have an important role to play by informing policymakers about the effects of hearing loss, not just the immediate effects. Audiologists are specifically trained deal with long-term effects of exposure to noise and the quality of life of the people exposed to such noise as discussed in chapter 6.

To briefly illustrate the importance of audiologists in the formulation of policies and regulations, in reviewing the 2003 MHSC milestones, the first milestone focused on the percentage of loss of hearing (PLH) in eliminating ONIHL. In the 2014 MHSC milestone, according to the information obtained from the participants, post consultation with audiologists, the focus shifted from PLH to standard threshold shift (STS).

The limited role and shortage of occupational audiologists in the mining sector may also be attributed to inadequate undergraduate training of occupational audiologists in South African universities. All participants except for one who trained in America reported their training as

occupational audiologists was lacking. It did not furnish them with adequate skills to carry out their duties. Currently, in South Africa, audiologists are trained over a four-year period and occupational audiology is not prioritised during this training. In America, obtaining a graduate degree, audiologists interested in pursuing occupational audiology receive supplementary training to enhance their knowledge (American Speech-Language-Hearing Association, 2004). This supplementary training offers specialised courses and reference materials from fields such as industrial hygiene, engineering, business, and public health (American Speech-Language-Hearing Association, 2004). This equips graduate audiologists with the necessary knowledge and skills to execute their role as occupational audiologists. There is therefore an urgent need for South African universities to provide adequate training for their occupational audiologists.

According to the National Center for Injury Prevention and Control (2011), without stakeholders' support, employees who are exposed to excessive noise may be ignored, resisted, criticised, or even sabotaged. Most studies investigating the management of ONIHL have ignored the importance of including employees as key stakeholders. HCPs are implemented to protect employees who are exposed to hazardous noise in the workplace. Therefore, employees must be educated on the need to safeguard their hearing. Consequently, training should focus on the specific individual benefits of HCPs where possible (Byrne, 2005).

Kanji, Khoza-Shangase, and Ntlhakana (2018) investigated the awareness of South African mineworkers on noise-induced hearing loss. Findings of study revealed the majority of participants (97%) were aware they worked in a dangerously noisy environment. Reportedly they aware of the consequences of noise exposure on their hearing function. However, less than 50% reported consistent use of HPDs. Furthermore, all participants were reportedly knowledgeable of the importance of hearing monitoring. However, they did not understand the meaning of their hearing

assessment test results. These findings attest to the importance of consulting and engaging with employees to gain their support and active participation in the management of ONIHL in the mining sector. Otherwise, without their support HCPs will ignored or even resisted (U.S. Department of Health and Human Services, 2011). Hence, there is a need to include employees as stakeholders in the management of noise, as they are an affected parties. This will empower them become active participants in minimising their exposure.

Participants in the current study also reflected on the importance of adopting "Leading Practice". They view it as a way of encouraging all stakeholders – miners and mine management – to develop initiatives and innovative ways of eliminating ONIHL in the mining sector. Leading practice was prompted by the realisation most mines were developing excellent and effective initiatives. However, they were working in isolation and not sharing their innovations with other mines.

According to Stewart and Malatji (2018, p. 265) leading practice is concerned with identifying and disseminating innovations in health and safety through "encouraging the mining industry to learn from the pockets of excellence that exists in the mining industry". Working as a group, and not in silos, fosters cross-fertilisation of ideas (Reidar, 2017). Consequently, the various mines might share strategies which have been viewed as effective in their operations.

Arguably, some ideas may not work for all mines – for instance, small scale versus large-scale mining do not have a same context. Therefore, in promoting leading practice, the mining industry need to take into account the context of each operation. Relatedly, chapter 7 argues for the importance of conducting realist reviews. Realist reviews facilitate understanding of what works at a specific mine, without comparing it to another mine. "Cross-fertilisation" allows for

transparent and meaningful exchanges of knowledge with the goal to achieve consequential decisions for improving occupational health and safety in the workplace (Reidar, 2017).

In synthesising all findings obtained in the current study, it became apparent HCPs have not successfully achieved what they set out to do in the South African mining industry. This lack of tangible and measurable success in implementing HCPs may speak to the fact HCPs are complex interventions. Complex interventions are implemented to improve the health of a population (Datta & Petticrew, 2013; Moore et al., 2015). The benefits of defining HCPs ,as complex interventions has an added advantage in that it allows realist reviews to be conducted. These take into account the context of the organisation in which the evaluation is being conducted (Pawson, 2006; Pawson et al., 2005).

For instance, let us look at Leading Practice in the current study. While some innovations may work in a large-scale gold mine, they make not necessarily work in a small scale mine where different ore is mined, or where a dissimilar organisational culture exists, and so on. Therefore, realist reviews may be the best way to evaluate the success and the barriers in formulating, implementing, evaluating and monitoring HCPs. Therefore, realist reviews, as presented in chapter 7, may pave a way for mines to understand the mechanisms contributing to the success and/or failure of HCPs within their contexts.

Furthermore, in responding to the challenges revealed by the current study, particularly the piecemeal fashion in which HCPs are implemented, this study proposes a feedback noise-monitoring tool in the management of ONIHL. This is presented in chapter 8 and discussed in the theoretical and practical contribution section of this thesis. Benefits of this tool include targeting and implementing all pillars of HCPs as well as the policies to ensure the code of conduct and

policies on ONIHL are actively integrated in implementing and monitoring HCPs in the mining sector.

9.4 Theoretical and Practical Contributions of the Research

This thesis yielded substantial theoretical contribution to research in the field of occupational audiology because of its recommendation to view HCPs as complex interventions which advances support for the realistic review approach as the best means to evaluate HCPs in the mining sector. Therefore, this thesis expanded on the works of Pawson (2006); Pawson et al. (2005); Pawson and Tilley (1997). Pawson et al. (2005) They argue public health services have shown an interest in evidence-based policymaking, despite the practical realities and challenges associated with using evidence in implementing policies.

These challenges are largely attributed to complex social interventions which act on multifaceted social systems such as performance measurements, regulations and inspections, etc. According to these authors "traditional methods of review focus on measuring and reporting on programme effectiveness often find the evidence is mixed or conflicting, and provide little or no clue as to why the intervention worked or did not work when applied in different contexts or circumstances, deployed by different stakeholders, or used for different purposes" (Pawson et al., 2005, p. 21).

Accordingly, these authors recommend the best method to obtain evidence-based reviews is by conducting realist reviews which are a relatively new strategy for synthesising research which has an explanatory rather than a judgmental focus. However, in order to conduct realist reviews,

the policies or projects being investigated need to meet set criteria defining them as a complex intervention.

Prior to conducting this study, complex interventions had not been conducted in the field of occupational audiology, specifically in the evaluation of HCPs. This was because HCPs were not defined or viewed as complex interventions. Consequently, it was not possible to conduct realist reviews in order to unpack and understand the mechanisms by which an intervention works or fails to work, by taking into account the context when methodically and transparently synthesising results (Pawson, 2006; Pawson et al., 2005; Rycroft-Malone et al., 2010).

Therefore, using the set criteria set out by Pawson et al. (2005), this study successfully argued for the recognition of HCP as a complex intervention. Recognising HCPs as a complex intervention, allows for conducting realist reviews in the implementation of HCPs. This has positive benefits for occupational audiology and the mining industry as well. As expanded from Pawson et al. (2005), benefits of conducting realist reviews in the South African mining industry include:

1. Providing CoM and DMR and the MHSC with further enlightenment and empirical evidence on the progress of HCPs implemented at every mine;
2. Assisting the MHSC interpret and clearly understand why HCPs worked better in one context than another e.g. small scale vs large scale or gold mine vs coal mine;
3. Providing MHSC with a justification for taking one course of action over another, e.g. prioritising buying quite over using HPDs
4. Alerting the CoM, DMR and MHSC to potential problems and specific measures can be applied to mitigate potential problems (Pawson et al., 2005).

Some factors negatively contributed toward achieving the MHSC milestone of eliminating ONIHL included challenges with policymakers not having clearly defined action plans as well as a lack of consolidated theoretical basis for their policies.

Therefore, conducting realist reviews may aid stakeholders and policymakers with evidence-based findings on the implementation of HCPs, and subsequently garner the benefits of realist reviews presented above. Thus, the current study has made a significant contribution in defining HCPs as complex interventions. This thereby allows stakeholders to conduct realist reviews to better contextually understand the HCPs implement at the various mines in South Africa.

This thesis also makes a practical contribution through the introduction of the feedback-based noise-monitoring model. This model is adapted from the Risk Management Framework from ISO 31000 (AIRMIC, 2010) and revised by the Australian Government-Department of Finance (Comcover, 2016). Risk management matrices have been conducted for years to rank diverse risks, particularly in the military. Recently, risk management has become a primary goal in numerous organisations (Dabari & Saidin, 2014; Donoghue, 2001). The benefits of risk management matrices for organisations include the ability to promote organisational outputs and create measureable value for stakeholders (Gates et al., 2012).

Defining risk management as the process of 'reducing the risk to a level deemed tolerable by society and to assure control, monitoring, and public communication' (Elmontsri, 2014, p. 1). Therefore, being cognisant, in other contexts such as the mining industry, the risk of noise hazard cannot be entirely eliminated. As a result, the current researcher proposed the use of a noise management matrix as a tool for managing ONIHL in the context of the South African mining sector. This noise management matrix was converted to a feedback-based noise-monitoring model,

where an engineering control approach was applied. While engineering controls are the first line of defense for removing safety hazards, the elimination and substitution of noise exposure are not always possible (National Institute for Occupational Safety and Health, 2016). This conversion resulted in a basic static feedback model which can be used to estimate, monitor and provide quantitative information to aid miners and mining administrators, as well as policymakers in decision making, thus reducing the impact of ONIHL in the mine. Additionally, the model forms promotes early detection and management of ONIHL in the workplace.

This model is unique in that, it takes into consideration the person's baseline audiogram as depicted in S1, while S2. It then takes into account the mandatory code of conduct policies or regulations guiding the mine on ONIHL. In short, S2 denotes policies such as the 2003 and 2014 MHSC milestones. S3 is the sensing unit of the model. The sensor used in this unit is the NIOSH Sound Level Meter mobile application tool (National Institute for Occupational Safety and Health, n.d). This sensor is used to measure sound levels in a mine and outputs noise intensity and frequency. S4 then takes into account other possible factors such as age, gender, medication etc. which may contribute to the individual's susceptibility to acquire a hearing loss.

Finally, S5 represents the check subsystem for monitoring developments of hearing threshold shifts. For annual and biannual check-ups, an audiogram is used to establish if a temporal threshold shift has resulted in a permanent threshold shift thus indicating damage to hearing resulting in ONIHL. Temporal check-ups may be performed on a weekly or monthly basis to establish the integrity of the inner ear hair cells of the cochlear.

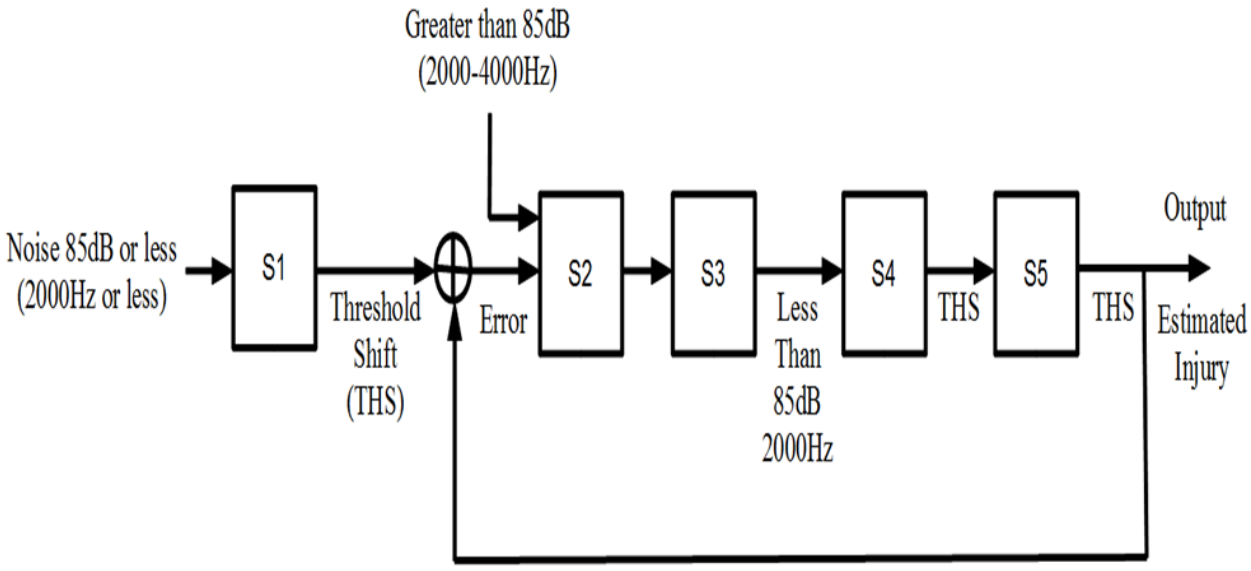


Figure 7: Overall system diagram for a feedback based model for NIHL monitoring (Moroe, Khoza-Shangase, Madahana, & Nyandoro, 2018)

Unlike present policies where the progress of the MHSC milestones are evaluated in 5-8 year cycles, this model provides a means for monitoring according to the organisation's needs. The current study also contributed in a practical way to the field of occupational audiology by highlighting the importance of the role of occupational audiologists in the management of ONIHL in the mining sector. This study also examines the challenges experienced by independent and objective researchers in accessing research sites in order to collect data.

This study has advocated for audiologists to play a more substantial role in hearing conservation in the workplace. This was achieved by highlighting benefits in including occupational audiologists in the formulation of policies on noise exposure. As well as by advocating for active in the implementation, monitoring and evaluating HCPs in the South African mining sector.

Equally, this study has also contributed to the field of audiology by highlighting the barriers faced by audiologists. These include inadequate undergraduate training and the silent position of the HPCSA on the scope of practice of audiologists as occupational audiologists in South Africa. It must be stressed audiologists are professionals trained and knowledgeable on the impact and consequences of poorly managed noise exposure in the workplace. Accordingly, audiologists' training and scope of practice should reflect this so they can successfully execute their roles in workplaces exposed to excessive noise.

Therefore, the practical contribution of this study speaks to the need for institutions of higher learning to evaluate the curriculum content they currently offer in occupational audiology. Alternatively, universities should consider offering postgraduate training in occupational audiology to better equip audiologists in their role as occupational audiologists. And lastly, the HPCSA must explicitly promote the role of occupational audiologist on the management of excessive noise exposure in the workplace.

Regarding restricted access, this study contributed to the field of occupational audiology. However, to conduct research, occupational health in general needs to be brought to the fore. This can be achieved by raising awareness of the many challenges faced by independent and objective academics as well as researchers in accessing research sites for data collection. A review of literature indicated studies have been conducted on the topic of occupational health and safety including ONIHL in the South African mining sector. The current researcher's experience of gaining access was a struggle. This raises questions as to the criteria used when seeking access into research sites.

Findings of the current study indicate a lack of progress in achieving the desired outcomes for the mining industry. The researcher argues restricted access may significantly contribute to this

failure. Restricted access to independent and objective researchers raises questions about enforcement or lack thereof of regulations by the regulatory bodies such as the CoM and DMR.

It is fully appreciated that individual mines have the liberty to exercise organisational autonomy. However, they are also legally liable for the provision of occupationally safe and healthy working conditions for their employees as stipulated in the Mine Health and Safety Act (President's office, 1996). It is also appreciated that in allowing organisations autonomy and enforcing regulations, the regulatory bodies, particularly the CoM, may experience conflicts of interest. However, production should not be prioritised over the health and safety of the employees. This was a precedence set by the apartheid regime (Kane-Berman, 2017; National Institute for Occupational Safety and Health [NIOSH], 1996).

This then raises key questions regarding how regulators assess adherence to regulations if the current study findings of a systematic gatekeeping of external, independent and objective academics and researchers are actually true. Furthermore, there are pertinent questions as to how the MHSC, a tripartite organisation representing state (DMR), employer (CoM) and labour (Unions) are stakeholders, policymakers and regulators of these regulations. How do they remain objective in providing quality assurance if individual mines restrict researchers' access to conduct research on occupational health and safety in this industry?

This finding of restricted access highlights the need for the mining industry and researchers to partake in a transparent discussion regarding the criteria used in granting access to researchers. Together, both sides must seek to establish evidence-based findings on the progress of HCPs implemented in the South African mining industry.

9.5 Limitations of the study

Current findings are significant and have made substantial contributions as detailed above. Nonetheless, these should be interpreted having taken cognisance of the following identified and acknowledged study limitations:

- This study was non-experimental in nature, and according to Knight, Kraemer, and Neuwelt (2005) the best study research designs are those which are experimental in nature and are backbone of good research. However, this is not to say non-experimental studies are not good research. Experimental studies also have their own limitations such as producing artificial results, and results are subject to human error (Writing@CSU, 2018).
- This study was qualitative in nature, as it made use of qualitative document analysis and in-depth interviews with various stakeholders. However, this presented a limitation methodologically. Recently, there have been calls for the use of mixed method designs in implementation research. This is particularly so in evidence-based and innovative practices as well as complex interventions, where relationships among stakeholders extend both vertically (state to local organisation) and horizontally (between organisations). Single methodological approaches are often inadequate (Landsverk, Brown, Chamberlain, Palinkas, & Horwitz, 2012; Palinkas et al., 2015). Mixed method designs are deemed suitable in implementation research as they provide a better understanding of research issues than either qualitative or quantitative approaches alone (Palinkas et al., 2011; Palinkas et al., 2015). Therefore, it should be noted in the conceptualisation of this study, a mixed methods approach was planned as the ideal research approach for this study, however due to the challenges in gaining access to the mine sites, the approach had to be amended.

- The sample size of this study was quite small with only 16 participants. The group was comprised of six representatives from the Mine Health and Safety Council representing the State, Labour and the Employer; seven audiologists; two ventilation and occupational health engineers and one occupational hygienist. Therefore, the findings of this study cannot be generalized to a larger population. However, it should be noted this study employed in-depth interviews. According to Dworkin (2012 p. 1319) "…in-depth interview work is not as concerned with making generalisations to a larger population of interest and does not tend to rely on hypothesis testing but rather is more inductive and emergent in its process". The current study was not concerned with generalising to a larger population, as the focus was to understand context specific information contributing to the success and/or failure of ONIHL in the South African mining sector. Furthermore, this study incorporated document analysis of eight documents and a systematic review of nine original research articles. Therefore, the inclusion of these items improved the sample size of the current study.
- The use of purposive sampling presents several challenges. Purposive samples, regardless of the type of purposive sampling is utilised, can be prone to researcher bias (Sharma, 2017). However, for the current study, in attempting to address possible researcher bias, member checks, peer reviewers as well as the community of practice were used throughout. In this study in particular, snowball sampling was used. However, snowball sampling also presents limitations. For example, it does not select units for inclusion in the sample based on random selection. Thereby, it minimises the possibility of determining likely sampling errors or making generalisations using statistical inferences from sample to population

(Sharma, 2017). As was mentioned earlier, this study was not concerned with generalising the current findings.

9.6 Conclusion

This study was undertaken in response to calls for evidence-based and comprehensive noise-control programmes in the South African mining industry. The study revealed an overall lack of progress in minimising and/or eliminating ONIHL in South African mines. This lack of progress is attributed to a number of reasons:

1. Lack of comprehensive and holistic studies addressing all the pillars of HCPs in the mining sector in South Africa.
2. Lack of clearly defined action plans, as well as poor collaboration among stakeholders.
3. Flaws in how HCPs, particularly, the MHSC milestones, were formulated, structured and implemented.
4. Gaps in the role of occupational audiologists in the management of ONIHL and implementation of HCPs in the South African mining sector.
5. Restricted Lack of access into the mining industry for research purposes.

The findings revealed HPCs currently implemented in the mining industry are not successful in eliminating ONIHL. This failure may possibly be due to the fact HCPs are not defined and treated as complex interventions. This thereby hinders researchers in conducting realist reviews to understand and unpack the mechanisms influencing the success and/or failure of HCPs currently implemented in the mining industry.

Therefore, the CoM, DMR, MHSC and occupational health and safety officers who are policymakers and stakeholders involved in policy formulation and implementation should endeavour to formulate evidence-based policies and HCPs in the elimination of ONIHL in the mining industry. This becomes particularly clear when one considers the context and history of mining in South Africa, and its perpetual effects.

9.7 Recommendations in terms of future directions

Notwithstanding the limitations of the current study, findings obtained from it provide solutions to significant challenges. Over and above an attempt to describe the management of ONIHL in the South African mining sector, this study provides an opportunity for the mining industry to define and view HCPs. There is now evidence to prove they are complex interventions and can present ways to conduct realist reviews which are contextually evidence-based measures of evaluating programmes. Furthermore, this study has proposed using a feedback noise-monitoring model as a means of comprehensively incorporating all pillars of HCPS as well as the code of conduct policies for the management of ONIHL in the mining sector.

Lastly, this study has highlighted and advocated for the role of occupational audiologists in the management of ONIHL in the mining sector. To date, audiologists have been disregarded by the mining industry, the HPCSA and institutions of higher learning in South Africa. Thus, implications raised by the current study can be translated into recommendations for policy formulation. Beyond this, further training of occupational audiologists and educating stakeholders on the long-lasting effects of ONIHL on employees exposed to excessive noise is necessary. Finally, further research in this area is absolutely necessary.

9.7.1 Recommendation for policy formation

- The main objective for conducting this study was to gather evidence-based information to be used by policymakers when planning the implementation of HCPs in the mining sector of South Africa. Findings from this study could therefore be used to motivate the mining industry to invest in prioritising engineering controls over HPDs. In this way, as suggested in this study, engineering controls in conjunction with awareness training on the long-lasting consequences of could potentially assist in reducing or possibly eliminating ONIHL in the South African mining sector.
- Policies formulated on the elimination of ONIHL in the mining sector need to include an active role for employees. They are the individuals directly affected by excessive noise exposure in the mining sector. Currently, MHSC milestones for the elimination of ONIHL focus on the source of noise and the use of HPDs. Based on this, it is possible to argue employees are active participants in the elimination of ONIHL as they are the users of HPDs. However, it must be remembered the findings of this study highlight the gaps in how employees are taught about the effects of exposure to excessive noise. Therefore, a need exists for policymakers to seek other means of making employees active participants in the management and elimination of ONIHL in their respective industries.
- Furthermore, still on the topic of policy formulation, policymakers should include occupation audiologists, not only in the management of ONIHL but in the formulation of policies and the implementation, monitoring and evaluation HCPs in the mining sector. It is therefore recommended the HPCSA expand the scope of practice of audiologists. More explicitly, they must include audiologists in the management of ONIHL occupational settings.

9.7.2 Recommendations for Institutions of Higher Learning

- Based on the findings of this study which has dealt with the preparedness and readiness for occupational audiologist to adequately perform their duties as occupational audiologists, there is still some distance to go. Universities offering degrees in audiology should consider enhancing their curriculum to include more information on occupational audiology in undergraduate training.

- International universities offer postgraduate occupational audiology training, therefore, it is recommended South African universities should do the same. They should consider making available postgraduate training in occupational audiology to those who want to pursue a career in this filed.

9.7.3 Recommendations for Education of Stakeholders

- It is recommended findings from this study should be used to educate the various stakeholders in the mining sector, not just the employees. Everyone concerned must be made aware of the impact and consequences of exposure to excessive noise in the workplace. Education can emphasise the impact of ONIHL on the health and safety of exposed individuals. Additionally, there is the financial implication for the individual, their families, the industry itself and the whole country. This is especially true for South Africa since it is a developing country with a quadruple burden of diseases (Yerramilli, 2015).

9.7.4 Recommendation for Further Research

- Given HPCs have been submitted as complex interventions, realist reviews should be conducted to review policies on ONIHL in the mining sector as well as any sector prone to excessive noise.
- Using the feedback noise-monitoring model introduced in this study, a further study should be conducted to demonstrate the application and benefits of this model with live cases.
- To date, in South Africa, no studies have been conducted on the economic cost of burden of ONIHL in the mining sector to quantify the economic impact of ONIHL. Conducting such a study may conscientise the mining industry regarding the cost of ONIHL on the individual, their families, the industry itself and the country as a whole.
- Occupational audiologists have reported they are not adequately trained in occupational audiology. Therefore, there is a need for another study to explore the feasibility of offering postgraduate training in occupational training.

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APPENDICES

Appendix A: Interview Questions for Stakeholders

SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)

Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Interview questions for stakeholders

1. Were you part of the stakeholders involved in the process of setting up the regulations or policies to reduce noise induced hearing loss among workers?
2. Whom were you representing?
3. At what stage of the programme were you involved?
4. Were you involved in the implementation phase?
5. What was your role in the implementation phase? Please elaborate
6. Were you involved in the monitoring and evaluation phase?
7. What was your role in the monitoring and evaluation phase? Please elaborate
8. What is your role currently?
9. Were audiologists involved at any stage of this programme
10. At what stage were the audiologists involved?
11. If yes, do you think the audiologist's input was valuable? Please elaborate

12. If no, do you think audiologists should have been part of this delegation? Please elaborate
13. In your understanding, what is the role of audiologists in the hearing conservation programme?
14. Overall, were the objectives of the regulations met? Please elaborate
15. What factors contributed to the success of the programme?
16. What factors were most challenging to the success of the programme?
17. When last was the programme evaluated?
18. What were the findings of the evaluation?

Appendix B: Interview Questions for Audiologists

SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)

Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Questions for audiologists

1. How long have you been an Audiologist?
2. How long have you been working as an occupational audiologist?
3. What does your everyday job entail? (Your case load, activities you engage in)
4. Is there a hearing conservation programme in this mine?
5. What is your involvement in the HCP?
6. Do you think that the management understand your role as an audiologist, please elaborate?
7. What kind of support do you get from management?
8. In your opinion, how effective is the HCP implemented in this mines?
9. What factors positively contribute to a successful HCP in this mine?
10. What barriers impact on the success of the HCP in this mine?
11. What do you think is the priority of management? (buying quiet vs production bonuses vs personal hearing protection devices)
    a. As an audiologist, what role do you play in influencing the decisions made by the management on the management of noise in this mine?
12. Do you know of any audiologists who sit in the management team?
13. Are you aware of the 2014 MHSC milestones?
    a. Do you think the mining industry will achieve these milestones, please elaborate?
    b. Do you think workers exposed to excessive noise are aware of long term impact of noise on their wellbeing?

c. How are mine workers educated or trained about the importance of conserving their hearing?

Appendix C: Medical Ethics Committee Clearance Certificate

R14/49 Ms Nomfundo Moroe

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M160264

NAME: (Principal Investigator)	Ms Nomfundo Moroe
DEPARTMENT:	Speech Pathology and Audiology Rand Mutual Assurance
PROJECT TITLE:	Occupational Noise Induced Hearing Loss in South African Large Scale Mines: From Policy Formulation to Implementation and Monitoring
DATE CONSIDERED:	26/02/2016
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof Katijah Khoza-Shangase
APPROVED BY:	Prof P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	18/04/2016

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 301, Third floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. 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 resubmit the application to the Committee. **I agree to submit a yearly progress report.** The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in February and will therefore be due in the month of February each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date 01/03/16

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix D: Request to conduct a Research Study for PhD degree purposes

SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)

Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

To: whom it may concern

RE: Request to conduct a Research Study for PhD degree purposes

Dear Sir/Madam

My name is Nomfundo Moroe, and I am a PhD Fellow at the University of Witwatersrand. As part of my PhD degree fulfilment, I'm conducting a study entitled: **Occupational Noise Induced Hearing Loss in South African Large Scale Mines: From policy formulation to implementation, monitoring and evaluation**. I would like to talk to you regarding your involvement in the 2003 Mine Health and Safety Counsel Summit where the state, labour and employer representatives signed an agreement with the mining industry to target two imperative milestones in the management of occupational noise induced hearing in the mines. These milestones were: to eliminate hearing deterioration greater than 10% as of December 2008 in individuals who are exposed to excessive occupational noise and to minimize the total noise emitted by any equipment to not exceed 110 dBA at any point in the workplace by December 2013.

In line with the milestones mentioned above, my study aims to understand the status quo in the management of occupational noise induced hearing loss in the mining sector. If you wish to participate, I would like to meet with you to complete an interview questionnaire which will take proximately half an hour (30 minutes) to complete. The interview will be tape recorded so that I can later listen to what is said during the interview. For your convenience, the questionnaire may be completed at your offices or telephonically in any of the 11 South African languages. During the interview, your name or any identifiable information will be not used; instead, your interview will be coded so that only the researcher knows your identity.

I have submitted my proposal to the Ethics Committee (Human Research Ethics Committee-Medical) at the University of the Witwatersrand for ethical clearance (Please see contact details below). There are no research-related risks in participating in this study and participation is completely voluntary. If you decide not to participate or withdraw from this study at any time, you are free to do so and it will not be held against you.

Human Research Ethics Committee-Medical:

Chairperson:

Professor P Cleaton-Jones

Tel 011 717 2301

Email: peter.cleaton-jones1@wits.ac.za

Administrative officers:

Ms. Z Ndlovu 011 7172700/2656 zanele.ndlovu@wits.ac.za

Mr Rhulani Mkansi 0117171234 rhulani.mkansi@wits.ac.za

Mr. Lebo Moeng 0117171252 lebo.moeng@wits.ac.za

If you have any questions, please do not to contact me on 0823178862

Yours faithfully

Nomfundo Moroe



Appendix E: CONSENT FORM

SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)

Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

CONSENT FORM

I, _____ (signature and date) hereby give consent to take part in this study. I have read the information provided above. I understand that participation is voluntary and that I can withdraw from the study anytime.

Appendix F: Permission to tape-record the interviews

SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)

Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Permission to tape-record the interviews

I understand that the interview will be tape-recorded and that the recorded tapes will be securely stored at the University of the Witwatersrand. I also understand that all information on the tapes will be confidential and that at no point will any reference be made to my personal details.

---------- ----------

Signature Date

Appendix G: Article 1: Research into occupational noise induced hearing loss in South African large scale mines: Access denied

Check for updates

RESEARCH ARTICLE

Research into occupational noise induced hearing loss in South African large-scale mines: Access denied? [version 1; referees: 2 approved with reservations]

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Abstract

Background: The South African mining industry is frequently criticized for its poor health and safety record and high numbers of fatalities, thereby prompting researchers to conduct research on challenges faced by this industry. Therefore, this study aimed to investigate the feasibility of conducting audiological research into occupational noise induced hearing loss (ONIHL) within the South African mining sector. Specific objectives involved determining ease of identifying focal persons in charge of hearing conservation programmes (HCP); establishing response time and rate of identified focal person for interviews; and exploring focal person's willingness to share information regarding HCP.

Methods: A qualitative research strategy comprising online desk research and interviews was undertaken through purposive sampling to recruit participants**.** Data were collected through checklists, logbooks and interviews. Deductive thematic analysis was used to analyse data.

Results: Gaining access into the mining sector is negatively impacted by the following factors: firstly, contact details of focal person are not always listed on the websites. Secondly, prolonged response rate between initial contact and the time in which the participants respond. Lastly, unwillingness to share information regarding the management of ONIHL and progress made in HCP at various mines.

Conclusions: Findings contribute evidence regarding possible barriers to effective and successful implementation of application of best practice in HCPs; guided by evidence that is contextually relevant. Challenges with accessing mines for research purposes by external and independent researchers arguably impacts on the available evidence produced by mines, due to a possible unavoidable conflict of interest. Success of HCPs depend on objective evidence regardless of whether it paints the mining industry in positive or negative light. It is only when this evidence is critically engaged with, that real and effective solutions can be deliberated and implemented. Clear, transparent, and open lines of communication between various stakeholders are key to achieving this.

Keywords

Access, audiologists, hearing conservation programmes, large-scale mines, response rate, focal persons, occupational noise exposure, South Africa

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Introduction

The mining industry in South Africa remains one of the driving forces behind the development of the country's economy. Currently, mining in South Africa is reported as a significant contributor to the economy in that firstly, it contributes an average of 20% to South Africa's GDP. Secondly, it boasts a total annual income of nearly 550 billion rand. Thirdly, it is one of the country's biggest employers with more than a million personnel in the workforce in mining-related employment, with the majority of the workforce being black males. Lastly, it has been regarded as the largest contributor by value to black economic empowerment in the economy (See article from Mining.com). However, the South African mining industry is frequently criticized for its poor health and safety record and high numbers of fatalities, although these conditions are reported to be improving. Ear and hearing health in the form of noise induced hearing loss is one of the health and safety conditions requiring the attention of the South African mining industry.

ONIHL is a prevalent condition in the mining industry and has been classified as a number one work-related disability, the second most common form of acquired hearing loss after presbycutic (age-related) hearing loss with severe consequences for those exposed to high levels of noise[1]. This type of hearing loss is not a phenomenon that is unique to South Africa only. In the United States of America, it is estimated that approximately 30 million workers are exposed to excessive noise in the workplace, and these workers are reported to be at risk of developing ONIHL[2]. In Europe, an estimated figure of 30 to 50 million workers are exposed to hazardous noise levels and are also at risk of developing ONIHL[3]. Approximately a million employees in Australia are potentially exposed to high levels of hazardous noise at work. In 2002, 4510 cases of compensation claims were reported and, and as a result, the number of hearing loss compensation claims was estimated at 4510 individuals in 2002, and this represented 19% of all disease-related claims were processed in the same year[4]. Locally, data from some South African mines indicate that almost half of the mines' workforce is exposed to hazardous noise and that 90% of these workers are exposed to noise levels exceeding 85 decibel A weighted (dBA) in intensity over and above an 8 hour working shift for a 40 hour per week time weighted average (TWA). Furthermore, 11% of the workers are exposed to noise levels that far exceed this 85 dBA limit[5].

Although hearing loss is not life threatening, unmanaged hearing loss may have a profound impact on the quality of life of the affected individual. Impoverished quality of life may manifest through reduced social activity, and feelings of exclusion from social participation, which may ultimately give rise to increased prevalence of symptoms of depression, stigma associated with hearing loss, loss of self-esteem[6]. Occupationally, noise induced hearing loss has a potential of reducing the worker's ability to perform or complete tasks that are dependent on auditory signals or verbal communication significantly[7]. Furthermore, due to hearing loss sustained at work, which subsequently results in a communication handicap, workers may be seen as incompetent or inactive, which ultimately, will impact on team work and group productivity[8]. Moreover, hearing loss can negatively affect communication among workers, which can lead to safety concerns as workers may not be able to hear warning signals such as sirens since high frequency sounds are the most affected. Compromised ability to communicate may lead to increased risks of accidents[9]. Additionally, ONIHL can present a limitation on the kind of employment suitable for a person with a hearing loss[7], which may possibly lead to economic burdens for developing countries in particular. Störbeck, and Moodley[10], argue that hearing loss represents a heavier burden in developing countries than in developed regions of the world because of the challenges faced by developing countries when compared to their developed counterparts. For instance, one of the biggest challenges in South Africa is that historically, black mine workers were not given an opportunity to obtain formal education. Consequently, most workers in the mining industry are illiterate and are restricted to performing jobs that require manual labour as these jobs do not often require any form of education[11]. This has lifelong implications for miners as they may not be employable due to illiteracy and hearing disability caused by excessive exposure to noise in the workplace, thereby rendering them eligible for worker's compensation. However, compensation pay-out may not be sufficient; consequently, these workers will be eligible for state pension, thereby adding to economic burdens in a developing country. Therefore to avert these negative conditions associated with ONIHL, it is important for audiologists, who are knowledgeable regarding the management of ONIHL as detailed in their scope of practice[12] to take an active role in minimising the impact of ONIHL on the exposed miner and to promote and advise on the implementation of hearing conservation programmes in the mining sector.

In 2003, the Mine Health and Safety Council (MHSC) in South Africa, comprising the State, Labour and Employer representatives signed an agreement with the mining industry to target two imperative milestones in addressing ONIHL in the mines[13,14]. The first target was to eliminate hearing deterioration greater than 10% by December 2008 in individuals who are exposed to excessive occupational noise. The second was to minimize the total noise emitted by any equipment to not exceed 110 dBA at any point in the workplace by December 2013. These milestones were reviewed and subsequently revised in 2014, as the mining industry did not meet these milestones. The revised 2014 milestones stipulate that: a) by December 2024, the total operational or process noise emitted by any equipment must not exceed a milestone sound pressure level of 107 dB (A). b) By December 2016, no employee's Standard Threshold Shift (STS) will exceed 25 dB from the baseline when averaged at 2000, 3000 and 4000 Hz in one or both ears[15]. The failure to achieve the initial milestones created the avenue for researchers to conduct studies into how these milestones can be achieved.

Post the failure for the mining industry to meet the 2003 MHSC milestones, the mining industry acknowledged that they are "not making the desired progress with noise-induced hearing loss, which is a major occupational health concern"[16]. Furthermore, the mining industry stated that ONIHL is "prominent in the

mining industry because action plans aimed at eradicating this disease are not as well integrated as they should be. We need far more comprehensive noise-control programmes"; however, the industry itself is committed to "the massive reduction and elimination of occupational noise induced hearing loss"[16].

The assertions by the mining industry highlight the importance of conducting research in this area to ensure that preventative measures are in place, the early identification of those with ONIHL occurs; and that early intervention is instituted. This is particularly important because enough evidence exists that illustrates the impact of unmanaged ONIHL. Therefore, in responding to these challenges highlighted by industry, independent researchers have embarked on conducting research into the mining sector with an aim to address these concerns. However, there seems to be challenges with allowing independent researchers access into the mines to conduct this highly needed research. Therefore, the current study aimed to investigate the feasibility of conducting research into the management of ONIHL in South African large-scale mines.

Methods

Research objectives

1. To determine ease of identifying focal person in charge of hearing conservation programmes in the mines
2. To establish the response time and rate of identified focal person for interviews regarding hearing conservation programmes in their mines
3. To explore the focal person's willingness to share information regarding hearing conservation programmes in their mines.

This study is part of a bigger study entitled "Occupational noise induced hearing loss in South African large scale mines: from policy formulation to implementation and monitoring".

Research design

A qualitative research strategy comprising secondary and primary data were used in the current study to collect and analyse data. The study had two phases: online desk research (secondary data) and conducting interviews (primary data). Phase one consisted of using secondary data in the form of external online desk research, which is a strategy for collecting data from existing online sources, outside the researcher's organization (See Management Study Guide Desk research methodology), to search websites of large scale mines as well as private and public companies affiliated to the mining industry in South Africa. Online desk research was undertaken to investigate the ease of identifying different stakeholders who are responsible for managing ONIHL in the mining sector. Desk research was conducted prior to inviting different stakeholders to participate in the study. Desk research can be conducted prior to embarking on a field trip (see User Focus article on Desk research).

Phase two consisted of inviting focal person identified from the online desk search to participate in interviews regarding the management of ONIHL in the mining sector. This phase of the study was concerned with determining the response rate and time of the participants recruited in this study. Furthermore, this phase investigated the participants' willingness to participate in the study.

Sampling strategy

Purposive sampling strategy was utilised in the current study as the researcher sought to, as discussed by Etikan *et al.*[17], identify and select individuals and group of individuals who have experience and are knowledgeable in the management of ONIHL in the mining industry. Furthermore, the researcher sought to recruit participants who are available and willing to participate in the current study. Possible participants were identified from the mining industry as well as private and public organizations affiliated to the mining industry. These participants were selected based on their work titles and credentials as listed in their personal profiles on the company's website.

Description of participants

Three sets of participants formed part of the current study.

1. Large scale mines in South Africa

According to the information obtained from the online desk research, 26 mines in South Africa were identified, of which 14 were large-scale mines. These mines produce different commodities such as gold, platinum, diamond, coal, heavy metal, and iron ore and are situated in various provinces across South Africa.

2. Public organisation affiliated to the mines and the state

This organisation is a national public entity which consists of a tripartite board represented by state, employer, and labour members under the chairmanship of the Chief Inspector of Mines. This entity is funded by public revenue and is accountable to parliament. The main task of this entity is to advise the Minister of Mineral Resources on occupational health and safety legislation and research outcomes focused on improving and promoting occupational health and safety in South African mines.

3. Private organisation affiliated to the mines

This organisation, founded in 1894, is a non-profit assurance company. It is the administrator of workers' compensation claims, including the medical payment of medical costs, once-off disability payments and the ongoing payment of pensions in the case of severe disability and death in the mining industry. Currently, there are approximately 26 mining companies under this administration.

Ethical considerations

Ethical clearance for the research study was obtained from the University's Human Research Ethics Committee (Medical) (Protocol Number: M160264). Prior to the commencement of the study, participants were provided with information letters detailing the purpose and the nature as well as ethical considerations of the study. Therefore, participants were informed first, that all the information obtained from the interviews will be kept

confidential. Secondly, any identifying information such as the participant's name or the name of the company they are affiliated with will be removed. Thirdly, participants could withdraw from the study without any negative consequences. Lastly, anonymity was guaranteed as participants were identified by the researcher, however, in one case, an invited participant requested to bring along a participant who had occupied her current position.

Consent forms were given to participants to sign, indicating that they have agreed to participate. Permission to digitally record the interviews was also requested and obtained. Participants were made aware that all the data collected from the interviews will be kept in a pin-protected computer and will only be made available to the supervisor for peer evaluation purposes. The recorded information will be destroyed after 5 years as per the university's protocol. Additionally, participants were made aware that the findings emerging from this study will be made available to the public through publications.

Data collection

For the first phase of the study, data were collected through the use of a checklist. The checklist was created by the researchers and it contains the following categories: immediate availability of the focal person; their contact details; their occupation/title and their professional background. The information obtained from the online desk research was then input on the checklist to document the findings of the search. The second phase of the study, data was collected through the use of interviews. To record the response time and rate as well as the participants' willingness to participate in the study, the research made use of a logbook. The logbook recorded the first time contact was made, when a response was received, if the researcher had to follow up with participants due to no response and the date and time when the appointment was made. For telephonic interviews, the same information was kept. Every contact and engagement between the researcher and the possible participants, the researcher entered that information on the logbook to supplement the field notes collected during the interview period. Therefore, a careful record of response time and response rate was a record of the key person's willingness to participate in the study as well as barriers identified.

Data analysis

Data was analysed using deductive thematic analysis as recommended by Creswell[18]. This method of analysis was chosen because, according to Gale *et al*[19]; Braun *et al*[20], in deductive thematic analysis, the researcher predefines themes based on specific research questions and the researcher's specific area of interest, as was the case in the current study. Therefore, the researcher printed all electronic communication and the manually recorded telephonic responses to the invitation to participate in the interview as well as the checklists and logbook used to collect data. The researcher read through all the text to immerse themselves into the data collected from online desk research and the logbook from the interviews. Thereafter, responses that pertained to ease of identifying focal persons, response time and rate as well as the willingness of the participants to share information was reduced to predefined themes as mentioned above. These themes were therefore reported using qualitative deductive thematic analysis.

Results

The findings of this study are reported according to the three sets of participants identified in this study as well as according to the objectives of this study which also served as predefined themes.

Objective 1: Ease of identifying focal person in charge of hearing conservation programmes in the mines

1. South African large scale mines

Out of the 26 South African mines that were identified online, 14 were deemed suitable to be included in this study as they were large-scale mines. The mines' websites were visited to identify persons to be invited for interviews. It was found that only six of the 14 mines had a focal person listed online. Of the remaining eight, six did not have a focal person listed and the remaining two did not display the members or executive managers of the company. Figure 1 below illustrates the number of mines which listed their focal person on their website.

With the six listed focal persons, it was not overtly documented that the identified focal person was indeed directly involved in the management of ONIHL or implementation of hearing conservation programmes. The assumption that they are somehow involved in HCPs was inferred from the occupational titles that they were given. For instance some were listed as:

- Executive Member: Mining and Safety, Health and Environment
- Executive Vice President: Sustainable Development comprises the disciplines of Safety, Health, Environment, Social and Community Affairs, Human Rights and Global Security, and Government Relations
- Chief operating officer (Safety, mining projects, new development and corporate strategy)
- Group Executive: Health and Safety
- Executive Head-Safety and Sustainable Development
- The Safety, Health and Environment (SHE) Committee

It is worth noting that these focal persons are occupying important or key positions which allow them to influence and promote the success of a hearing conservation programme at their respective mines. As can be seen below, Figure 2, three of the focal persons identified had a background in mining engineering, one in biological sciences; while two had no backgrounds listed.

All the identified focal persons did not have their contact details listed with their names and occupations. To contact these individuals, one would need to contact the company's secretary telephonically or electronically. When the researcher attempted to contact the focal person through the company's provided email address, an automatic acknowledgement of

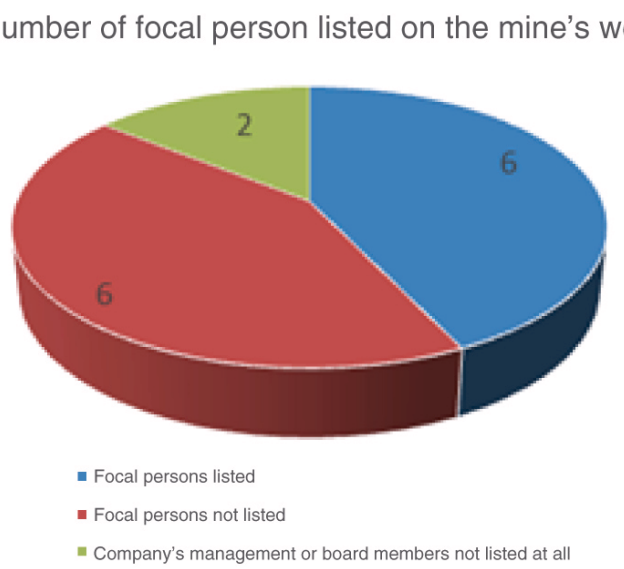


Figure 1. Number of focal persons listed on the mine's website.

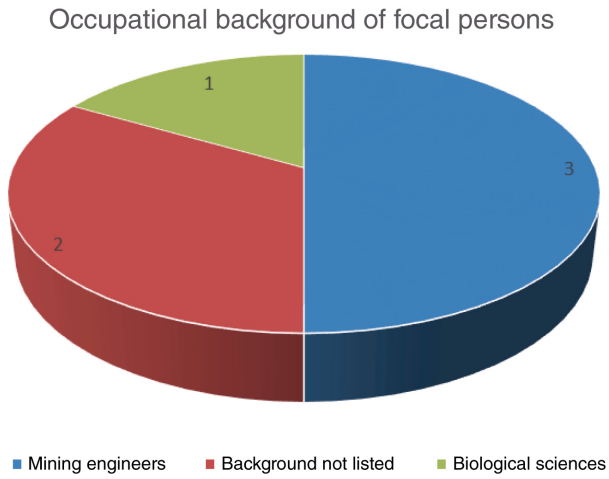


Figure 2. Occupational background of focal persons.

receipt email was sent to the researcher, however, no responses were subsequently received from either the company's secretary or the focal persons identified. When the company was contacted telephonically, the calls were either unanswered or transferred to the focal person's personal assistant. The personal assistants generally stated that the identified focal person had a busy schedule therefore; they will be unable to make time for the interviews. Some personal assistants requested the contact details of the researcher with a promise to contact the researcher once the focal person was available. Unfortunately, the researcher was not contacted by any of the personal assistants or focal persons. Consequently, none of the identified listed focal persons participated in this study.

Due to the fact that large scale mines are integral to this study, the researcher had requested help from the Chamber of Mines to assist with identifying focal persons who are directly involved with the HCP in the mines. To date, the researcher is still in contact with the large scale mines requesting permission to access the mines and to invite focal persons to participate in the study through interviews.

2. Public organisation affiliated to the mines and the state

This search identified 14 focal persons. Eight responded to the request to participate in the study, but in the end, only six participated in the interviews. The focal persons were identified with ease. The organisation's website provided and listed all

the members of this organisation and their affiliation: Labour, State and Employer. However, the individual's contact details were not provided. The researcher contacted the company's receptionist and requested the contact details of all the listed focal persons. The receptionist provided the telephone contact details of the personal assistants of the focal persons. The personal assistants were contacted and were able to provide email addresses of the focal persons. Following which, the identified focal persons were contacted electronically via email to invite them to participate in the study. Eight focal persons responded to the email indicating their willingness to participate in the study. However, due to time constraints, only eight participants participated in the interview. Interviews were conducted face-to face with five participants and one participant requested a telephonic interview as they were unable to commit to a specific time due to the nature of their job. Two participants, who were part of the face-to-face group requested to do the interview together. This arrangement was made as the other focal person had recently joined the company and they felt that they might not be in a position to answer all the questions which might require institutional memory. Figure 3 shows the breakdown of the tripartite members who participated in this study.

Of the six participants, one was from labour, one from the State and four from the employer. As with the focal persons identified from the large scale mines, for these participants also, their roles as individuals were not clearly stated. However, the mission and vision of the company itself was listed. Five participants had a medical background before joining this organisation and still continue working in their capacity as medical doctors for various employers.

Private organisation affiliated to the mines

Identifying focal persons from this organisation's website was difficult. The website lists the board and executive members; however it does not list their occupations. To know more about the role of each person listed, one needs to click on the person's name to get their profile. The researcher read the profiles of all the persons listed under executive management, and was still unable to identify the focal person involved in the management of ONIHL in the mines. Furthermore, none of the listed executive managers had their contact details listed. The researcher then attempted to contact the organisation to find out who the focal persons to approach were through the call centre number. The receptionist reported that they cannot provide the contact details of any staff member to the public. The research was advised to email the organisation's secretary and the email will be directed to the relevant person who will then contact the researcher. The researcher emailed and received a notification stating that the email had been received and the relevant person would respond to the email. The organisation was emailed twice; and on both occasions, other than the email stating that the sent email had been received; no response was received from the relevant person.

During the interviews with one of the participants from the public organisation affiliated to the mines and government, the researcher shared with the participants the challenges faced with finding participants for the study. It was at this stage that this participant furnished the researcher with the contact details (cell phone numbers) of the two focal persons at the organisation affiliated to the mines. This participant first obtained permission from the focal persons before giving the contact details to the researcher.

Following obtaining the contact details of the focal persons, the researcher contacted the two focal persons from OAM telephonically and none of them responded. The researcher then opted to utilize short messages service (sms) to contact them and requested their email addresses. A few days later, one of the contacted focal persons responded and provided the researcher with their email address. This focal person also has a background in medical science.

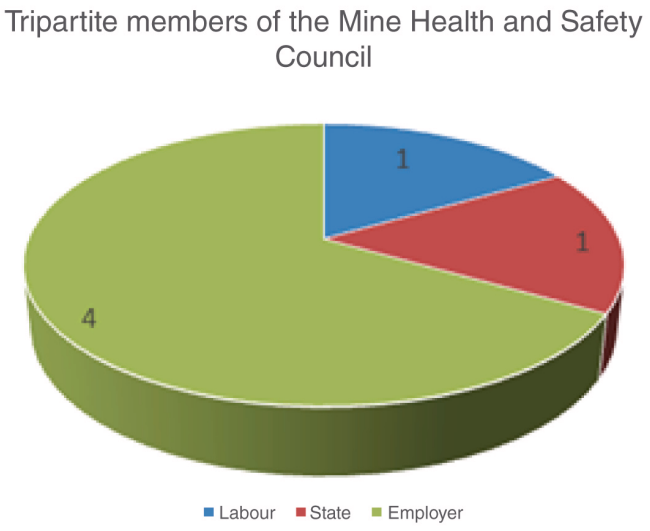


Figure 3. Tripartite members of the Organisation affiliated to the mines and the state who participated in the study.

Objective 2: The response time and rate of identified focal person for interviews regarding hearing conservation programmes in their mines

1. Large scale mines

To date, it is rather difficult to report on the response rate of the large-scale mines as none of the mines have committed to participating in the study. It suffices to say that it is now over 18 months since the initial request to gain access to the mines to collect data was made and still there is no response. This has led to the researcher having to explore other avenues to collect data for the main study. So far, only one mine committed to participate in the study; however, mine executives and managers have not participated in the interviews. This mine has however, partially furnished the researcher with some of the requested data. The discussions between this mine and the researcher are still on going.

2. Organisation affiliated to the mine and the state

Contact with OAMS was initially initiated on 19 April 2016. After obtaining contact details, Table 1 below details the response rate in the current study.

3. Organisation affiliated to the mines

OAM was initially contacted telephonically in April 2016 to request the contact details of the focal persons. The researcher was advised to send the request electronically, using the company's email address. The email was sent the same day, after speaking to the company's secretary. The response was received immediately stating that the email has been received and will be forwarded to the relevant person. Exactly, 14 days later, in May 2016, the researcher sent another email to follow-up and requested another appointment. However, the same reply was received.

Upon realizing that this response was an automatic reply, it became a likely probability that no response was forthcoming. After obtaining the contact detail of the focal persons at OAM, the researcher contacted the two focal persons telephonically in July 2016. One focal person responded immediately and provided the email address to which the researcher sent her request and invitation. The focal person also stated that they were away from the office.

Mid July, the focal person forwarded the researcher's email to the general manager. A week later, after not receiving a response from the focal person, the researcher sent a sms to check whether the focal person received the email. The focal person responded immediately stating that they received the email and were awaiting feedback from the General Manager. Later on the same day, the researcher received a response with an invitation to a meeting in the first week of August 2016. In total, it took 18 days from the initial positive contact with a focal person to having a meeting. These focal persons did not participate in the interviews.

Objective 3: The focal person's willingness to share information regarding hearing conservation programmes in their mines

1. Large scale mines

The researcher is still in contact with various mine focal persons in order to continue requesting to be granted permission to access the mines for data collection. Of the focal persons that the researcher was able to contact from the list provided by the Chamber of Mines, two focal persons categorically told the researcher that they will not allow the researcher access to the mines. When the researcher enquired into the reasons why the researcher will not be allowed access, one focal person responded by stating that they have their own people conducting studies at their mine, so they will not allow any more researchers. The other stated that they were undergoing a restructuring process, so they will not be allowing any researchers into the mines. Another focal person indicated that they were interested in allowing the researcher to conduct their study at the mine but needed to request permission from the management team. However, this focal person has not responded to follow-up emails ever since.

2. Organisation affiliated to the mines

No further engagements took place between the research and this focal person as they stated that the research should contact the mines directly to obtain the required information.

3. Organisation affiliated to the mines and state

Generally, at face value, some members seemed eager to share the information with the researcher; but there were restrictions

Table 1. Time period between initial contact to conducting the interviews.

Participant	Affiliation	Responded first time round	Responded after follow-up	Type of interview	Total number of days
1	Labour	Yes	-	Face-to-face	12
2	Employer	Yes	-	Telephonic	16
3	State	-	Yes	Face-to-face	28
4	Employer	-	Yes	Face-to face and teleconference	51
5	Employer	-	Yes		51
6	Employer	-	Yes	Face-to-face	78

to how much could be shared with the researcher. For instance, one participant requested that the researcher provides background information and involvement with the mines before agreeing to participate in the interview. After the researcher gave the background, the focal person then participated in the interview. During the interview, the focal person shared some figures on the prevalence of ONIHL based on the report that was shared with the focal persons at the last health and safety summit. The researcher requested the copy of the report, and the focal person promised to send this to the researcher as soon as they returned to their office. A few days later, the researcher contacted the focal person again to request the report; and the focal person could not remember which document the researcher was referring to. The researcher has not received this document to date.

The researcher was advised by one of the participants to search the internet for the documents. Upon following the advice, the researcher searched the internet for the requested documents; however, there were challenges with accessing most of the documents relevant to main study. This was due to the fact that one needs to be registered with different companies in order to have access to files. Therefore, these files were not obtainable. When meeting with one of the focal persons, the researcher mentioned the difficulties in accessing online documents due to restricted and controlled access, the focal person responded by stating that "if one found answers easily, there would not be a point in doing research. It is called research because you have to do some searching."

Another participant requested to do a telephonic interview provided the researcher sent them the interview questions electronically to preview the content of the interview before agreeing to the interview. The researcher informed the focal person that it was not possible to send them the interview questions. This participant than requested to have a face to face interview after office hours as they were unable to find a suitable time during office hours. Also, this participant stated that they wanted to see the person they were giving the information to. During the interview, the participant mentioned their weariness with sharing information with researchers as researchers often misinterpret the data and quote people out of context. Furthermore, this participant requested a copy of the completed thesis to verify the content of the report. One more participant requested to be sent the questions in advance in order to prepare for the interview.

Discussion

Current results illustrate the difficulty with the ease of identifying focal persons involved in the hearing conservation programmes in large-scale mines in South Africa. This difficulty is further exacerbated by the fact that, even where the focal persons are listed, their positions simply list the general health and safety position; with their exact role in the management of noise not overtly stated. This is deemed a challenge as Byrne[21], asserts that the first step mines should consider before implementing a hearing conservation programme is addressing administrative issues; where company regulations or policies are clarified, and where individuals' responsibilities and roles are identified and enforced. The roles and the responsibilities of individuals should be listed on the company's website for the ease of contacting the relevant persons should the need arise.

From current results, it was noted that of all the focal persons identified in this study, none had a background in audiology. Arguably, the fact that most of the persons/people interviewed either had a background in mining engineering or medical sciences might imply that they may have some knowledge about the impact of noise on the wellbeing of individuals exposed to excessive occupational noise. However, international evidence suggests a need for focal persons with a background in audiology. The American Academy of Audiology suggests that the audiologist is the principal advocate for and supervisor of programs that manage the hearing health of people exposed to hazardous noise[22]. This is based on the training and scope of practice of audiologists which states that "the audiologist designs, implements, and coordinates occupational and community hearing loss prevention programs which includes identification and amelioration of noise-hazardous conditions, identification of hearing loss, recommendation and counselling for use of hearing protection, employee education, and the training and supervision of non-audiologists performing monitoring audiometry in the occupational setting"[22 no page,23]. This statement therefore highlights the important role that audiologists should have in the key positions in the management of noise induced hearing loss in the mines.

The fact that all the focal persons identified as being involved in management of noise at various mines in the current study, occupy key positions in the executive management at the mines is an important finding. This indicates the importance mines seem to place on ONIHL; and it also suggests that these individuals are in strategic positions where they are able to advocate and promote hearing conservation programmes at the mines.

As far as the response time and rate of identified focal person for interviews regarding hearing conservation programmes in their mines; current findings were disappointing. The results revealed that the minimum timeframe from when initial contact was made to the when the interviews were conducted is 12 days, with maximum at over 18 months. This is a concern for researchers as in most cases; studies are conducted within fixed time frames. Delays in obtaining data timeously may affect the quality and the completion of the study. This poor response time and rate also raises implications for prompt and efficient evidence-based interventions to reduce or eliminate ONIHL in the mines. Research provides evidence base that is both contextually relevant and contextually responsive; and so engagement in objective research that has minimal to no conflict of interest is important for mines to engage in in order to use best practice in HCPs instituted in the mines. This willingness to engage in objective research was demonstrated to be challenging in the current study.

As far as focal person's willingness to share information regarding hearing conservation programmes in their mines, current findings indicated that the identified focal persons are guarded when it comes to willingness to share information. The fact that participants wanted pre-access to the interview questions and also wanted to approve reports written about the study indicated some level of high anxiety and suspicion about the type and nature of information they can or cannot share; and a demonstrated fear of revealing information that might be deemed damaging to the individuals concerned or to the company. This restriction in information might have a significant impact in reality-based planning where real and accurate evidence is used to plan efficacious interventions.

Conclusions

Current findings regarding the ease of identifying and accessing focal persons involved in hearing conservation programmes in various large-scale mines in South Africa highlight the challenges faced by researchers in identifying and gaining access into the mines. Findings from this study highlight the perceived lack of transparency in the management of occupational noise induced hearing loss in the mining sector. This has implications for the mines as these findings suggest that focal persons are not easily identifiable and their roles are not clearly stated. Furthermore, the fact that the majority of the focal persons do not respond promptly to requests for interviews is concerning as opportunities to share information and knowledge on the management of noise induced hearing loss in the mines are lost and deliberations on efficacious HCPs reduced. Sharing of such knowledge may assist in identifying the factors that contribute both positively and negatively to the success of the hearing conservation programmes in various mines. Lastly, the fact that some participants requested to pre-view the interview questions creates the idea that there is certain information that should not be made available to the researchers or interested parties. Such a practice may hinder the success of the hearing conservation programme as information deemed confidential may not be shared thereby impacting negatively on the success of hearing conservation programmes in large scale mines. This is particularly important within an ethically approved research environment where researchers are bound by the ethical code of conduct which includes confidentiality and anonymity.

These findings highlight the importance of clearly demarcated and documented roles of key members in charge of HCPs; with clear communication lines. Findings indicating the minimal or absent role of audiologists in ear-specific occupational health within the South African mining industry raise important concerns which the Health Professions' Council of South Africa and the Department of Labour might need to deliberate on for future planning around noise pollution and the role of audiologists in the management of noise in the work place.

In conclusion, the authors do acknowledge that managers of private and public organizations are at liberty to resist independent investigations of health and safety hazards faced by their employees in the workplace. However, current findings potentially can make management appear derelict in their responsibilities towards their employees in the management of noise. These findings might even pressure regulatory agencies to enforce regulations in the mining sector regarding transparency and ease of access to information for researchers. Such outcomes may be unpleasant from a management point of view; however, for HCPs to achieve their goal, such findings are important to share.

It is anticipated that all stakeholders involved in HCPs, and possibly other programmes relating to other health and safety concerns in the mines, will deliberate on the challenges presented in this paper and identify how these could be contributing to their inability to reduce and/or eliminate health hazards in the workplace. It is also hoped that this paper will spark debate within the mining sector about the reasons for the position of "in-house" research that seems to be prevalent; and how this could be negatively influencing their goals and targets with regards to health and safety.

Data availability

The purpose of this study was to investigate the feasibility of conducting research into the management of ONIHL in South African large-scale mines. The focus was on the ease of identifying focal persons in charge of hearing conservation programmes, establishing response time and rate of focal persons to participate in interviews and the participant's willingness to share information regarding hearing conservation programmes. Raw data from the interviews is not provided as the findings of this study do not include use of interviews to answer any of the questions mentioned above. Furthermore, personal electronic conversations between the researcher and stakeholders will not be made available on the public domain as this correspondence was of a personal nature. This correspondence was used to create a logbook for analysis. Therefore, data only in the form of checklists and logbook is available (please contact the corresponding author).

Competing interests

No competing interests were disclosed.

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Appendix H: Article 2: The management of occupational noise induced hearing loss in the mining sector in South Africa: A systematic review

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Review

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The management of occupational noise–induced hearing loss in the mining sector in Africa: A systematic review – 1994 to 2016

Nomfundo Moroe, Katijah Khoza-Shangase, Amisha Kanji and Liepollo Ntlhakana

Abstract

Literature into exposure to occupational noise in developing countries suggests that the prevalence of occupational noise–induced hearing loss is still high. There is also evidence that the mining industry is aware of this epidemic; however, the efforts to curb occupational noise–induced hearing loss are currently unsuccessful. Therefore, the aim of this study was to explore and document current evidence reflecting trends in the management of occupational noise–induced hearing loss in the mining industry in Africa from 1994 to 2016. A systematic literature review was conducted in line with the Cochrane collaboration guidelines and Preferred Reporting Items for Systematic Reviews and Meta-Analysis. Electronic bibliographic databases such as ScienceDirect, PubMed and Scopus MEDLINE were searched. A total of 1212 titles and abstracts were identified; of which only nine papers formed part of this study. The results indicated that there is a dearth of research on the management of occupational noise–induced hearing loss in Africa. The limited research on the management of occupational noise–induced hearing loss focuses on some aspects of the hearing conservation programme pillars and not on all the pillars as suggested by some scholars in the field. Furthermore, these studies had small sample sizes thereby, minimizing their generalization. There is therefore a need for more studies on the management of occupational noise–induced hearing loss in the mining sector, as there is evidence to suggest that occupational noise–induced hearing loss in African countries is still on the rise.

Keywords

Developing countries; hearing conservation programmes; hearing loss; mining industry; occupational noise

Background

The South African Mine Health and Safety Council (MHSC)[1] states its goal as 'every mine worker returning from work unharmed everyday: Striving for zero harm'. As far as ear and hearing health, this goal, however, has not been realized despite the concerted efforts from the MHSC and the Chamber of Mines in South Africa. The reality is that approximately 73.2% of miners in South Africa are exposed to excessive noise surpassing the legislated occupational exposure limit of 85 dB, despite hearing conservation programmes (HCPs) implemented in the mining sector.[2,3] HCPs are multi-component interventions aimed at managing noise-induced hearing loss in a workplace.[4] Well-integrated and comprehensive HCPs are those that encompass all seven pillars namely: periodic noise exposure monitoring, engineering controls, administrative controls, personal hearing protection, audiometric evaluations, employee/management education and training and record keeping.[5] Amedofu and Fuente[6] argue that the success of HCPs depends on the implementation of all the pillars of the conservation programme.

Numerous studies have been conducted to evaluate the effectiveness and efficacy of management of occupational noise–induced hearing loss (ONIHL) within the South African mining industry. These studies have yielded unfavourable findings, which indicate that significant efforts are still required to successfully manage ONIHL.[7–9] Published evidence indicates that the prevalence of ONIHL is high in developing countries such

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as South Africa. Storbeck and Moodley[10] maintain that hearing loss represents a heavier burden in developing countries than in developed regions of the world because of the challenges faced by developing countries when compared with their developed counterparts. Moreover, ONIHL can present a limitation on the kind of employment suitable for a person with a hearing impairment,[11] which may possibly lead to economic burden for developing countries in particular. Establishing the status of ONIHL and its management in developing countries becomes important if strategic planning around this occupational health challenge is to be systematic and successful. It is therefore with this backdrop that this study was conceptualized. This study aimed to explore and document current evidence reflecting trends in the management of ONIHL in the mining industry in Africa.

Methods

Data sources and literature search

To identify studies reporting the management of ONIHL in the mining industry in Africa, a systematic literature review was conducted in line with the Cochrane collaboration guidelines[12] in conjunction with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[13] The electronic bibliographic databases that were searched included ScienceDirect, PubMed, Scopus MEDLINE, ProQuest and Google scholar. The search terms used (PubMed mesh terms) included 'occupational noise induced hearing loss', 'occupational noise AND hearing loss', 'work- related noise' OR 'hearing loss' OR 'hearing impairment' OR 'disability', 'noise in the workplace' AND 'Africa' OR 'African' OR 'sub-Saharan Africa' AND 'management' OR 'managing' OR manag* 'addressing' OR 'intervention' AND 'mining' 'min*'.

Inclusion criteria

Articles selected for inclusion in this study were original pieces of scientific work or reports published in peer-reviewed scientific journals. These articles were conducted in the mining sector in Africa between January 1994 and December 2016. The focus was on the management of ONIHL in the mining sector in Africa. All the articles were published in English.

Data extraction and synthesis

First, articles to be selected for inclusion were independently identified by four investigators (N.M., K.K.-S., A.K. and L.N.) using pre-defined abstraction. Disagreements on papers selected for inclusion were resolved through discussion and consensus among all four researchers. Where consensus was not reached, N.M. as the leading author made the final decision. Second, authors provided a narrative synthesis of the findings from the studies that met the inclusion criteria. The synthesis included the study objectives, study design, study setting and management strategy used in the included studies.

Results

Study identification

A sum of 1212 titles and abstracts were identified, from which 1195 were identified from the databases mentioned previously and 17 manual reviews of the reference lists of the identified publications. A total of 798 titles and abstracts were excluded due to duplication. Around 414 abstracts were screened, and 377 were removed post abstract review, as they did not meet the criteria in terms of being conducted in the mining sector in Africa. Consequently, only 37 articles were subjected to a full-text review, of which 28 were excluded as they were not original research articles or peer-reviewed. Eventually, a total number of nine studies were eligible for inclusion in the study. Of the nine articles reviewed, two focussed on the use of engineering controls; one on administrative controls; four on the use of personal protective devices, and one on education and training as a means of eliminating ONIHL in the African mines. Figure 1 presents the PRISMA flow diagram describing the process of study selection. The findings of each selected study were reviewed and synthesized qualitatively, as there was substantial heterogeneity among the studies reviewed.

Studies characteristics

Study designs. Four studies used cross-sectional descriptive research designs where structured questionnaires and face-to-face interviews, and observations were used to collect data. One study used a retrospective record review of audiograms to analyse the efficacy of an HCP; while another study used multiple measures personal qualitative observations, empirical theory evidence and quantitative descriptions. One study used a web-based survey design; another used functional analysis; while another used workshops utilizing obstacle-based planning techniques (Table 1).

Study settings. Of the nine studies included, seven were conducted in mining contexts in South Africa, while of the remaining two; one was conducted in Ghana and the other in Zimbabwe.

HCP pillar targeted as a means to manage ONIHL in the mines. The reviewed studies focussed on four of the seven documented pillars of successful HCPs. These pillars included engineering controls, administrative controls,

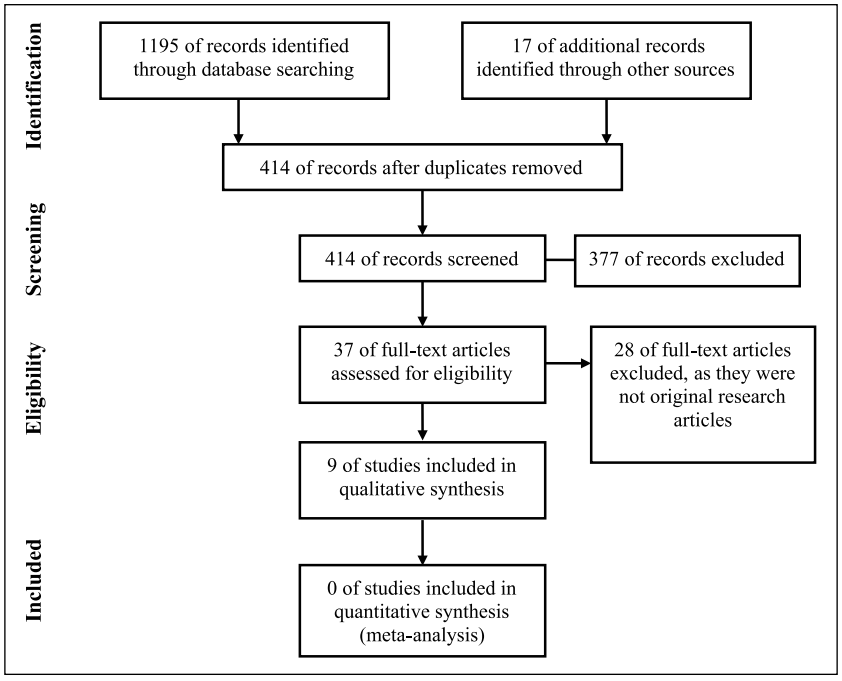


Figure 1. The PRISMA flow diagram describing the process of study selection.

personal protection devices, as well as education and training. Current findings on these four pillars are presented in this order below.

1. Engineering controls

Two studies focussed on the use of engineering controls as a means to reducing noise at its source in the mining industry. First, in a study by Gumede et al[14] development of a proposed strategy and structure for the buying quiet initiative (BQI) was investigated. This initiative focussed on adopting and promoting the use of quieter machines as a strategy of controlling noise at its source. Findings of this study highlighted that the mining industry does acknowledge BQI as a proactive strategy that will significantly reduce ONIHL and improve the management of noise at its source. However, this study also identified a number of obstacles in the implementation of BQI. The most serious obstacle concerned the formation of a well-constituted industry-wide task team which should include various representatives from relevant and key industry stakeholders. Furthermore, concerns regarding proper scoping, management leadership and the mining industry's adherence to the initiative were raised. Moreover, lack of involvement by stakeholders as well as economic constraints were also identified as potential obstacles in the implementation of BQI.

Second, in a study by Burger et al.,[21] the focus was on developing a low-noise blast hole drilling system in order to reduce the risk of ONIHL in the mining operations. The rationale for this study highlighted the benefits of using this drill such as removing the operator from the areas of excessive noise and minimizing the need for operators to support the drill, thereby eliminating the risk of vibration-induced injury. Results from this study indicated that the developed low-noise rock drill achieved the noise level specification as stipulated in the legislation, thereby enabling the mining industry to be compliant with the ONIHL regulations.

2. Administrative controls

Of the studies reviewed, only one study focussed on administrative controls. This study was conducted by Steenkamp[19] and aimed to contribute towards best practice according to the ISO with regards to implementing HCPs in the mines. Therefore, this study revisited existing HCPs to report on the trends in order to address the weaknesses of current hearing conservation practices in South African mines. This study presents the six-sigma model, which seems to be a useful model that can serve as a quality management tool of HCPs and assist in managing ONIHL. It advocates for personalized aspects of HCPs such as custom-made hearing protection devices (HPDs). Implementing this model requires that all the pillars of the HCP be subjected to measurement. These measurements should include audiometric testing and monitoring of ONIHL using objective measures as well; worker orientation and education related to HCP; optimal and appropriate custom-made HPDs, as well as consistent use of HPDs by workers.

Table 1. Describes details of study characteristics of each included study.

Author(s) & date	Research title	Research focus/aims	Methodology	Context	Results
Edwards et al.[8]	Evaluation of the current practices of noise-induced hearing loss (NIHL) awareness training in the South African mining industry	Evaluation of practices of mining companies in relation to the criteria for best practice of NIHL awareness training	Descriptive survey design. Questionnaires followed by interviews with managers responsible for HCPs	Six mining companies in South Africa-national representation. 30 managers were interviewed.	No commitment to NIHL training by all mines. No theoretical basis for NIHL awareness training. More than half of the mines did not evaluate the employee's knowledge after training. No measure of whether the training is effective or assisting with achieving specific goals
Gumede et al.[14]	Strategy towards a mining industry-wide Buy-and-Maintain Quiet initiative to reduce noise-induced hearing loss	To identify the factors on which the success of a Buy-and-Maintain Quiet initiative will depend – an initiative aimed at reducing NIHL by reducing noise at its source	Workshops using obstacle-based planning techniques	South African mining industry	Number of obstacles preventing implementation of BQI. Lack of involvement by relevant stakeholders. Poor collaboration in the industry. Poor scoping in terms of having dedicated task teams
Ntlhakana et al.[15]	The use of HPDs in South Africa: exploring the current status in a gold and a non-ferrous mine	To investigate mine workers' current use of HPDs in South African gold and non-ferrous mining subsectors; to determine factors influencing the use of HPDs and their relationship to gender, level of education and years of experience and to determine factors associated with the use of HPDs in these workers	Descriptive study design. Face-to-face structured interviews were conducted, using a self-developed questionnaire	Gold and non-ferrous mines in South Africa	Every miner was provided with HPDs, but disposable corded foam earplugs were observed to be used by the majority of participants. Majority of participants stated that they used HPDs at all times during the 8- to 10-h shifts. The reduction of the risk of hearing loss and protection from loud noise exposure and reduction of dust contact with the ear canal were reported as benefits of HPD usage. Factors related to comfort, design and ability to manage work-related communication and warning signals influenced HPD usage
Steenkamp (2008)[16]	A personal approach to hearing conservation: the key to effective second-level noise control	To determine current HPD status and developments and to investigate the current trend to use custom-made HPDs for personal hearing protection as a catalyst for personal hearing conservation.	Web-based survey design using a self-developed Likert-type scale questionnaire	Manufacturing and mining companies in SA	Nearly all respondents (87%) anticipate that HPDs will become a more important means of hearing protection. Respondents indicated a clear need for improvement in the standards of HPDs used. The best and preferred HPDs are the custom-made types. 78% of respondents agreed that each worker will need to be managed individually, custom fitted with an appropriate HPD, personally trained and serviced (at least once annually). Comfort was the most frequently chosen minimum standard (97%), followed by hygiene. Yet when forced to choose only one of the above, signal detection increased. Comfort and user-friendliness were noted for improved HPDs
Amedofu et al.[17]	Effectiveness of hearing conservation program at a large surface gold mining company in Ghana	To determine the effectiveness of an HCP at a surface gold mining company in Ghana.	Retrospective review and comparison of individual audiograms from 1999–2003	Large surface gold mining company in Ghana	Out of the 200 audiograms, which were examined, 11 (5.5%) showed an increase in thresholds of more than 10 dB (i.e. indicating worsening hearing levels), while 3 (1.5%) showed a decrease in thresholds (i.e. hearing levels showed an improvement)

Table 1. (Continued)

Author(s) & date	Research title	Research focus/aims	Methodology	Context	Results
Mutara and Mutanana[18]	An analysis of an Hearing Conservation Programme (HCP) at a mining company in Zimbabwe	The study sought to carry out an analysis of an HCP at a mining company in Zimbabwe	A mixed mode approach in which both qualitative and quantitative paradigms were used. The quantitative aspect entails obtaining quantitative data through questionnaires. The qualitative approach entails data collection using in-depth interviews	Mining company in Zimbabwe	The mine under study is providing hearing protective devices and the majority of the workers are making use of them. However, it would appear that the HPD conservation programme is suffering a setback from some employees who do not want to use them, for instance, general hands and artisans. None of the workers are using the dual protective method, a standard that is recommended by several researchers. The researchers observed that the company is doing well in carrying out audiometry tests during annual medical examinations. To this end, the medical interval has been found to be adequate for the employees
Steenkamp[19]	A six sigma-based management model to eliminate the noise-induced hearing loss pandemic in South African mines	To contribute towards best practice ISO hearing conservation programme standard by revisiting hearing conservation, existing HCP models, new trends and eventually addressing the weaknesses of current hearing conservation practice in South African mines. To present a hearing conservation model as a foundation for future research	Research methodology using several measuring instruments in a combination of personal qualitative observation, empirical evidence, theory and quantitative description. The six-sigma methodology based on secondary research and a case study from a platinum mine	South African mining industry	The six-sigma model is a powerful model that can serve as a quality management of HCPs and assist in managing NIHL. It is beneficial when looking at personalized aspects of HCPs such as custom-made HPDs. The model requires that each dimension of the HCP model be subjected to measurement. These dimensions include audiometric testing and monitoring of NIHL using objective measures as well; worker orientation and education related to HP; optimal and appropriate HPDs that are custom made utilization of HPDs by workers
Hansia and Dickinson[20]	HPD usage at a South African gold mine	To determine the actual and reported use of HPDs in noise-exposed gold mine workers and their reported knowledge, attitudes and practices relating to NIHL and HPDs	A cross-sectional descriptive study was conducted, in which 101 noise-exposed mine workers were interviewed and their use of HPDs observed	South African mining sector	The majority of participants correctly indicated that they worked in noisy environments, that their noise exposure could damage their hearing and that HPDs are beneficial. Reported use (93%) was notably higher than the observed use (50%). The higher the skill level, the greater the proportion observed using HPDs. Reasons for not using HPDs included discomfort, interference with hearing warning signals, HPDs not working or falling out of the ears. Eight percent of respondents indicated that they were never informed about the benefits of HPDs
Burger et al.[21]	Design and development of a low-noise rock drill	Development of a low-noise rock drill system	Functional analysis	South Africa	Noise levels of under 90 dBA were achieved, thereby attaining the primary design specification

HCP: hearing conservation programme; HPD: hearing protection device; NIHL: noise-induced hearing loss; ISO: International Organization for Standardization; BQI: buying quiet initiative.

3. HPDs

Four studies focussed on the use of HPDs as a means of managing ONIHL. While these studies indicated that the use of HPDs is a preferred method; there were challenges associated with the use of HPDs in the mines.

First, Ntlhakana et al[15] conducted a study in the gold and non-ferrous mining subsectors in South Africa and focussed on the use of HPDs in the workplace. A total of 90 mine workers from two mines (Gauteng province: 65 and Limpopo province: 25) were interviewed using a questionnaire with open- and close-ended questions. Direct observations were incorporated in this study where underground miners were observed to verify if they used HPDs when working in noisy places. Findings of this study confirmed the ineffectiveness of the HCP programme as far as the use of HPDs was concerned. All the participants in the study reported using HPDs; however, comfort, design and work-related communication were identified as barriers to poor and inconsistent use of these. Also, the authors specifically reported that participants were aware of the importance of protecting and preserving their hearing; however, this was not motivation enough to use HPDs; therefore, prompting the need for more focussed education on the impact and implications of exposure to hazardous noise levels in the workplace.

Second, in a study conducted by Hansia et al,[20] the actual and reported use of HPDs by participants exposed to excessive noise at a gold mine was explored. Furthermore, this study assessed the workers' reported knowledge, attitudes and practices relating to ONIHL and HPDs use. This study consisted of 101 participants who were interviewed and observed during their work shifts. The authors reported that some participants (13%) erroneously indicated that their workplaces were not noisy, while 16% did not think that noise was a hazard in the workplace, and 6% were not aware of the importance of using hearing protection when exposed to excessive noise. Around 3% reported that they believed HPDs did not protect hearing. In this particular study, while the majority (n = 93) of the participants reportedly used HPDs, only 50% were observed using their HPDs consistently. A small number (8%) of participants reported that they were not informed about the benefits of using hearing protection despite being informed. The authors reported that the participants claimed that HPDs were uncomfortable; hence their poor adherence to their use. Around 57% preferred other training methods other than the current computer-assisted training. However, the other preferred methods are not listed.

Third, in a study by Steenkamp,[16] the aim was to determine the occupational effects of quality hearing protection in terms of health, safety and productivity. Moreover, this study also documented the testimony and the experiences of using a custom-made hearing protection device (CHPD). Findings in this study revealed that workers used their CHPDs, and this was recorded as a great improvement when compared with standard HPDs use. The results also reinforced that CHPDs are a preferred choice in terms of the workers' medical and occupational hygiene hearing ability status. Furthermore, CHPDs improved work in terms of quality, safety and productivity. In addition, the workers who were fitted with CHPDs expressed satisfaction with this type of protection.

Finally, the fourth study by Mutara et al[18] aimed to analyse an HCP at a mining company in Zimbabwe. This study consisted of 120 employees who completed individual questionnaires and took part in a focus group discussion. Findings of this study indicated that the company provided HPDs (plugs, noise-ban customized hearing devices and earmuffs) to their employees and that the majority of the employees used the HPDs to protect their hearing. Furthermore, in this study, the company conducted annual audiometric testing for all employees. However, there were setbacks identified as some of the employees did not use their HPDs despite having been educated on the how and the why of using hearing protection. This prompted the authors to recommend that the company should enlist the services of a resident audiologist to assist non-compliant employees.

4. Education and training

Edwards et al[8] conducted a descriptive survey to evaluate ONIHL awareness training programmes in six mines in South Africa. Findings of this study, first, indicated that there was lack of prioritization of commitment to awareness training, and that this challenge received little priority in all the participating mines. Second, findings revealed that a large majority of the mines (80%) lacked a solid and consolidated theoretical basis for their awareness training programmes. Third, language used during the awareness training seemed to be an influencing factor where there did not appear to be a standard language policy followed. In this study, the awareness training programmes were conducted 30% in English only, 40% in the employees' language of choice and 30% combined English and Zulu. Finally, findings from this study revealed that 60% of the participating mines did not evaluate employees' acquired knowledge post training.

5. Audiometry evaluation

Amedofu et al[17] sought to examine the effectiveness of an HCP in a large surface gold mine in Ghana. In this study, a retrospective review and comparison of mine workers' audiograms from 1993–2003 was conducted. A total of 200 mine workers participated in this study. According to this study, the implementation of HCP was introduced in 1999 at the research site. The results revealed that hearing loss worsened in 5.5% of the participants, while in 1.5%, hearing function improved. The authors concluded that

evidence from their study indicated that the HCP implemented in Ghana was effective, as over 90% of the participants did not present with further hearing loss during their study. The conclusion from this study seems to have been solely based on the audiograms obtained from the mining company and data were collected from one large-scale mine with only 200 audiograms having been evaluated. This identified limitation in the methodological design of the study suggests that concluding that HCP was effective based on such a small population may have been premature and a similar study with a larger sample may yield more accurate results.

Discussion

This review study identified nine studies which met the inclusion criteria for the systematic review. The studies that were selected were heterogeneous; therefore, attempts were not made to conduct a quantitative synthesis or meta-analysis.

Although ONIHL is not life threatening, unmanaged hearing loss may have a profound impact on the quality of life of the affected individual[22] as ONIHL is irreversible and untreatable as the hair cells, once damaged, cannot be restored.[5] However, ONIHL is preventable through a systematic and comprehensive effective HCP that includes all eight pillars of HCPs.[5,17]

During this study's qualitative synthesis, it was noted that no single study attempted to comprehensively and holistically address all the eight pillars of an HCP in the mines. Current authors believe that the failure of conducting comprehensive and holistic studies may be attributed to the fact that HCPs are complex programmes or complex interventions with multiple and multifaceted component/pillars conducted in complex environments with various sources of noise and various stakeholders. Conducting such comprehensive studies may be time consuming; and may require significant resources and commitment from different stakeholders. Regardless of these challenges, current authors believe that if the South African mining industry is fully committed to the elimination of noise and its impact in the mining industry, such studies will need to be conducted to ensure that interventions yield successful HCPs.

Studies reviewed in this study only focussed on four pillars, in a piecemeal fashion; namely engineering controls; administrative controls; personal hearing protection and education and training. These studies neglected periodic noise exposure, audiometric evaluations and record keeping. Overlooking periodic noise exposure monitoring has implications for the entire programme as this pillar serves to identify individuals exposed to excessive noise in the workplace.[23] According to the Workplace Safety and Health Council,[23] noise monitoring should be conducted every time any alterations are introduced and applied on the machines or every 3 years, if there are no changes introduced in the workplace.

Another pillar that was not featured in any of the studies reviewed was record keeping. To maintain accountability, effective record keeping is crucial and it requires commitment and consistency, as ONIHL develops gradually and overtime; therefore, keeping records of each employee becomes crucial, as records can be used to determine the employee's exposure to noise.[24] Proper record keeping allows for effective and accurate programme evaluation which is important for programme sustainability if successful; and/or programme changes where challenges are identified.[24] Proper record keeping also allows for accurate and appropriate individual conservation programme implementation where employees' compounding factors such as concomitant exposure to other toxins (e.g. co-occurrence of TB and HIV with ototoxicity) can be taken into careful consideration in employee HCP plans. Furthermore, proper record keeping allows for accurate comparative analysis of employee thresholds for compensation purposes; should this eventuality come. Proper record keeping also facilitates accurate research to be conducted to allow for relevant evidence base that can be accessed by the mining industry to enhance their HCPs. With regards to the pillars that were targeted in the included studies, majority focussed on the use of personal hearing protection. While some authors have argued that HPDs remain the most used method of prevention of ONIHL despite their limitations; they also emphasize that HPDs are fully effective when used in conjunction within a comprehensive HCP.[4,25–29] However, the Department of Minerals and Energy in South Africa[30] strongly recommends that the use of personal protection devices should be regarded as the last resort if engineering and administrative controls and audiometric evaluation measures fail. Current evidence, however, suggests that there is an over-reliance on hearing protection devices in the workplace.[5,31–33] This was also evident in this study as the majority of the studies focussed on HPDs. Furthermore, it should be highlighted that there are challenges associated with the use of HPDs such as discomfort, negative impact on work-related communication and the design of the HPDs as was reported by the studies included in this review. Several authors[15,31,34] support that these challenges impact on compliance and adherence to using HPDs. These findings have profound implications for industries that do not use HPDs as part of a comprehensive HCP as they imply that workers who find their HPDs uncomfortable, they will expose themselves to hazardous noise in the absence of other effective HCPs measures protecting their ears against noise injuries. Therefore, it is also the view of the current authors that HPDs; although, seemingly they minimize the amount of sound energy to the ear, should be used in conjunction with the engineering and administrative controls – and not as a primary strategy.

It is encouraging that three studies conducted in this review focussed on the use of engineering and administrative controls to combat noise in the mining industry.

Conducting such studies is critical as engineering and administrative controls are the first line of defence against exposure to loud noises.[24,35] The ideal goal is to reduce the noise levels at the source so that other elements of the HCP are not needed.[24] The benefits of implementing administrative controls and engineering controls include 'permanence, effectiveness with or without worker/supervision compliance, less absenteeism, easier communication, lower worker compensation costs and reduced legal costs'[33],p.33. For engineering and administrative controls to be effective, management has a responsibility to make sure that noise sources that can be controlled through these controls are identified and prioritized and that the resources are allocated accordingly.[36] The results of this study highlighted the benefits of implementing engineering and administrative controls; however, they also highlighted the obstacles such as lack of commitment from management and poor formation of key task team members. According to Patel et al,[37] the lack of enforcing regulatory requirements in the workplace is the major downfall to the success of engineering controls. In addition, there is a misconception that implementing noise controls is too arduous and costly; hence, the lack of synchronized distribution of information regarding the importance of noise controls in the workplace.[33] Although the argument of noise controls being too costly is legitimate; current authors believe that this cost is a once off monetary cost as opposed to the significant benefits to the health and quality of life of employees in the immediate and long run. The benefit also includes the elimination of compensation costs, which might increase significantly in the future with improved employee awareness of their rights as well as health and safety regulations.

Victor Hugo, a French author and playwright once stated 'No cause can succeed without first making education its ally'[38],p.6. These sentiments were highlighted by the studies included in this review.[8,15,18] Patel et al[37] reported that most of the barriers experienced by the miners can be addressed by simply educating and training them on the importance of preserving their hearing. Stanton[39] rightfully emphasized the importance of educating, not just the miners but the management also on hearing conservation practices. Education and motivation are a priority in minimizing hearing loss in the mines as they create opportunities for both management and employees to discuss and agree on commitments, communication lines and cooperation.[24] Training can be conducted to explain various and pertinent topics such as the effects of noise on hearing, as well as the purpose and value of wearing HPDs. In a training programme, advantages and disadvantages of hearing protectors being offered by the company can be discussed in detail. Also, this may serve as an opportunity for highlighting the miners and operators' responsibilities in maintaining noise controls, while also describing the purpose and the value of audiometric testing.[24] If individuals understand the reasons and the benefits of an HCP, they are more likely to participate, especially if training addresses the specific needs of individuals exposed to excessive noise. Current authors strongly concur that all the stakeholders and policymakers involved in the management of ONIHL should be trained in the long-term impacts and effects of ONIHL regardless of whether these stakeholders and policymakers are exposed to noise or not. This is especially true for the management and employers who may not be directly exposed to noise as knowing and understanding the impact of noise may guide the stakeholders and policymakers in implementing HCPs that are realistic and relevant.

Although one study focussed on the use of audiometry surveillance as a means of monitoring employee's exposure, it should be noted that this study was based on archived record reviews. This is not in line with the Occupational Health and Safety (OSHA) standards. According to OSHA,[40] audiometric evaluations are conducted to monitor an employee's hearing status over a period of time; as they play an important role in the HCP. Audiometric evaluations help identify employees who may be at a risk of developing occupational hearing loss.[23] Audiometric evaluations serve as an early detection process, since the symptoms of hearing loss do not readily manifest until a significant threshold shift occurs.[23] For effective evaluation, audiometric evaluations should be conducted at pre-employment; prior to assignment to a work area that has high volumes of noise; annually, if the employee is still working in a noisy area; when being reassigned to another area after being exposed to noise and finally, at the termination of employment.[40] The two most important audiograms in the HCP are the baseline audiogram and the annual audiograms.[40] Furthermore, audiometric evaluations serve as an opportunity to educate and train employees about the importance of preserving their hearing as employees who understand the objectives of an HCP are more likely to protect their hearing.[40] Employers are mandated to keep audiometric evaluation results for as long as the worker is employed. Therefore, this study highlights the need to conduct ongoing baseline and annual audiograms.

Over and above the aforementioned challenge identified in this review of the fact that no single study focussed on comprehensive HCP (inclusive of all pillars) in the management of ONIHL. There were also shortcoming with the methods used to collect data. Of the studies that utilized interviews and questionnaires and archival record reviews, the highest number of participants included was 200. These small sample sizes negatively impacted the ability of the findings to be generalizable.

Conclusion

Evidence-based interventions founded on best practice are critical in any health and safety programme. The fact that HCPs are complex interventions that include a variety of

factors and a range of stakeholders, with diverse influencing factors; current findings are concerning. First, the fact that there is such limited research conducted on HCPs in Africa is a significant drawback to the collation of contextually relevant evidence that can be used to implement effective HCPs; and the fact that most of this evidence was from South Africa alone is an even bigger concern. Second, the piecemeal fashion of studies that have been conducted, where individual pillars instead of comprehensive holistic HCP analysis is done also impacts negatively on identifying gaps and/or weak links in any HCP. Third, the fact that only four of the pillars have been investigated over the review period limits the amount of evidence available to the mines as well as evidence for future planning. Finally, the fact that the studies reviewed generally included small sample sizes means that findings from these studies are not easily generalizable to the African mines generally. Current findings, which provide an overview of studies in HCP and ONIHL in Africa, add to the evidence base which can be consulted in planning future studies, in formulating policies around hearing conservation and in planning and implementation of HCPs. These findings should be interpreted taking careful cognizance of the design and methodology adopted in the review.

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Appendix I: Article 3: Management of occupational noise induced hearing loss in the mining sector in South Africa: Where are the audiologists

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Original

Management of occupational noise induced hearing loss in the mining sector in South Africa: Where are the audiologists?

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Abstract: Objective: This study was conducted to explore the scope of practice for occupational audiologists in the mining industry and the audiologists' involvement in hearing conservation programmes in South African mines. Additionally, this study investigated the mining industry's role in the audiologists' involvement, and assessed the audiologists' levels of preparedness for working in occupational audiology. **Methods:** In-depth, qualitative telephone and face-to face interviews were conducted with seven occupational audiologists involved in the management of occupational, noise-induced hearing loss (ONIHL) in the South African mining sector. Snowball sampling was utilized to recruit possible participants for this study. Data were analysed using inductive thematic analysis. **Results:** The following themes were identified: scope-context misalignment, juniorization of the experts, audiologists are important… but for what?, and limited training in occupational audiology. **Conclusions:** Our evidence highlights important gaps in HCPs in South Africa. The fact that the audiologists responsible for the management of ONIHL are only minimally and peripherally involved may play a significant role in the lack of progress reported in the management of ONIHL in the South African mining sector.
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Key words: Audiologists, Conservation programmes, Hearing loss, Mining industry occupational noise, South Africa

Background

The audiology profession in South Africa (SA) is less than 100 years old, with only six of the country's 26 universities offering the training. The training of professional audiologists in SA has its origins at the University of the Witwatersrand[1)]. The first programme was established in 1938 by Pierre de Villiers Pienaar, who established the Speech, Voice and Hearing Clinic in the University of the Witwatersrand[1,2)]. Approximately 200 audiologists graduate each year. These audiologists have to work in government hospitals as part of a compulsory year of community service. Post-community service, the majority of audiologists go into private practice, with a small number retaining government hospital jobs. This migration from government is influenced by a number of factors such as the structure and availability of government posts, which are accompanied by poor working conditions and resource constraints. Graduates register with the Health Professionals Council of South Africa (HPCSA) and are regulated by this council, with no involvement from South African Society of Occupational Health Nursing Practitioners (SASOHN). Consequently, their practice tends to neglect occupational health, specifically occupational noise induced hearing loss (ONIHL).

The prevalence of ONIHL remains one of the challenges in occupational health management in SA[3)]. However, this challenge is not one of the South African Health Department's targeted priorities. Although the burden of disease that dictates health priorities includes conditions that are prevalent in the mining industry such as HIV/AIDS and TB, not enough attention is paid to this part of health - occupational health. Therefore, assessment and management of ONIHL is a neglected public health issue.

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Currently, ONIHL falls under the purview of the Department of Labour as part of their occupational health and safety mandate, with no oversight or accountability to the HPCSA or the Speech Language and Hearing Professions professional board, which is responsible for regulating the scope of practice of professionals dealing with ear and hearing function. The result of this fragmented structure is that there is no audiologist-led, structured, and well-coordinated hearing conservation program within the South African mining industry.

The American Academy of Audiology promotes audiologists as the principal advocates and supervisors of programs that manage the hearing health of people exposed to hazardous noise[4]. Audiologists are tasked with "designing, implementing and coordinating occupational and community hearing loss prevention programmes. These roles require the identification and amelioration of noise-hazards, the diagnosis of hearing loss, offering recommendations and counselling on the use of hearing protection, employee education, and training and supervising of non-audiologists performing monitoring audiometry in occupational settings"[5]. However, the American Speech-Hearing-Language Association (ASHA) (1999) reports that few audiologists serve as consultants in the mining industry, and even fewer are involved in noise measurements, the training of occupational hearing conservationists, or hearing conservation programme audits and evaluations. In SA, there is a dearth of literature on the involvement of audiologists in the management of occupational exposure to hazardous noise in the workplace.

Current evidence indicates that the South African mining industry is aware of the existence of audiologists and their role in the management of occupational exposure to excessive noise. According to section 43 of Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) audiologists are 'competent persons' in carrying out baseline-hearing level surveillance of people exposed to occupational noise in the workplace[6]. This document also states that occupational medical personnel and medical practitioners specializing in otorhinolaryngology are 'competent persons' as long as they are registered with the HPCSA. Furthermore, audiometrists are also listed as 'competent persons': "A person with a qualification in audiometric techniques obtained from an institution registered with the South African Qualification Authority or any of its structures in terms of the South African Qualifications Authority Act, 1995 (Act No. 58 of 1995), and registered with the South African Society for Occupational Health Nursing" (SASOHN).

Dr. de W. Oosthuizen compiled the Guidelines for a Hearing Conservation Programme for the mining industry[7], which details the role of occupational audiologists in the management of ONIHL. According to this document, this role is limited to conducting medical surveillance, thereby significantly reducing the role of occupational audiologists. The limited role of occupational audiologists is inconsistent and not in compliance with ASHA's[8] scope of practice as described above.

Therefore, this study aims to investigate the role of occupational audiologists in hearing conservation in the South African mining sector. This work is part of a larger study titled: Occupational Noise Induced Hearing Loss in South African Mines: From Policy Formulation to Implementation and Monitoring. The aim of this study was to explore the involvement and role of occupational audiologists in HCPs in the South African mining industry.

Methods

Study design

In-depth interviews were conducted for this qualitative study. Qualitative research uses a naturalistic approach in seeking to understand phenomena in context-specific settings without the influence of the researcher, eliminating manipulation of the phenomena of interest and allowing it to unfold naturally[9,10]. Furthermore, qualitative research seeks to illuminate, understand and explore a phenomena in its native context[11]. This study sought to illuminate and understand the involvement and role of audiologists in HCPs in the South African mining sector. Therefore, a qualitative approach was suitable for achieving this objective.

Sample size and sampling strategy

A sample size of seven occupational audiologists was obtained and interviewed for the study. The number of audiologists is relatively small; however, this in itself is a finding of this study, as it indicates the very limited involvement and employment of trained audiologists in the South African mining industry. When recruiting participants for this study, we discovered that the South African mining industry prefers to employ audiometrists over audiologists for occupational audiology work. Therefore, our small sample size validates the importance of the study, as it attests to the absence of occupational audiologists in the mining sector. Since this study consists of a small sample, its findings cannot be generalized to a larger population. However, this study is based on in-depth interviews, and according to Dworkin[12], "in-depth interview work is not as concerned with making generalizations to a larger population of interest and does not tend to rely on hypothesis testing but rather is more inductive and emergent in its process."

Due to the small number of occupational audiologists in the South African mining industry, snowball sampling was used to recruit participants. Snowball sampling is a strategy where participants approach other people who meet the inclusion criteria defined by the researcher, and request that they also participate in the study[13]. Snowball sampling was particularly important in this study as occu-

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Table 1. Profile of participants.

Participant	Nature of affiliation to the mine	Years as occupational audiologist	Gender	Age
1	Private company affiliated with a mine	2.5	Male	36
2	Private practice affiliated with a mine	5	Female	32
3	Employed at a mine	8	Female	36
4	Private contractor at a mine	12	Female	43
5	Private practice affiliated with a mine	21	Female	47
6	Private contractor at a mine	37	Female	62
7	Private company affiliated with a mine	8	Female	40

pational audiologists are rare and difficult to locate. Therefore, we took advantage of the social networks of identified participants to expand the set of potential participants, allowing a series of referrals to be made within a circle of acquaintances[14]. However, snowball sampling is limited in that it does not recruit a random sample. Therefore, the sample used in this study may not be representative of a larger population[15]. Participants were initially identified through a Google search for occupational audiologists in the mining sector. These audiologists were contacted via email and phone, and were requested to participate in the study and to suggest other study participants.

Inclusion criteria

Participants were required to be occupational audiologists who have worked in the mining industry for more than 6 months. Participants had to be aware of HCPs implemented in the mines. Additionally, participants had to be occupational audiologists either in private practice and contracted to the mines, or in private companies affiliated with the mines. The participants' profile is shown in Table 1.

In-depth Interviews:

Interview questions were formulated based on the available literature and analysis of regulatory documents, policies, and acts on the management of ONIHL in the mining industry. The interview structure followed the recommendations by Rubin and Babbie[16], where the interviewer possesses a plan of inquiry as well as a set of questions. Furthermore, Kerlinger and Lee[17] recommend that similar questions be grouped together in order to maintain cohesion and order. Research questions focused on undergraduate training, occupational experience, workload, and involvement in HCPs. All of the interviews were conducted in English and were audio-recorded.

Ethical considerations

All procedures contributing to this work complied with the relevant national and institutional guidelines for research on human subjects, and adhered to the Helsinki Declaration of 1975 as revised in 2008[18]. Furthermore, approval was obtained from the University of the Witwatersrand Human Research Ethics committee (Medical; Protocol number M160264). Ethical issues such as confidentiality and the right to withdraw from the study were discussed with the participants. However, anonymity was not guaranteed due to the use of snowball sampling in this study. Participants were made aware that all information given to the researcher would be kept confidential.

Data analysis

Transcribed data was analysed through inductive thematic analysis. Inductive thematic analysis is a process of coding data "without trying to fit it into a pre-existing coding frame, or the researcher's analytic preconceptions. In this sense, this form of analysis is data-driven"[19]. Themes that emerged from this data were analysed using the steps recommended by Braun and Clark[19]: familiarization with the data, generation of initial codes, searching for themes, reviewing themes, defining themes, and writing-up findings. Representative verbatim quotations are used to support the presented findings.

Trustworthiness

In order to address any biases or subjectivity in the handling and analysis of data, the authors acknowledge that "all research is subject to researcher bias"[20]. Therefore, a peer reviewer served as a mirror and assisted in reflecting responses to the interviews. Also, the authors made use of the "community of practice"[21] to share the process and findings with a group of colleagues who are experienced researchers and are familiar with the role of occupational audiologists. Furthermore, while transcribing the interviews, the researcher contacted participants when further clarification or additional information was required, and this information was in turn given by the participants.

Results and Discussion

The following themes were identified in the data: scope-context misalignment, juniorization of the experts, audiologists are important, but for what?, and limited

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training in occupational audiology. These themes are discussed below.

Theme 1: Scope-Context misalignment

Participants were asked to briefly discuss their typical caseload in order to ascertain their everyday involvement at the mines. Participants indicated that their caseload consisted of ear pathologies, hearing tests, and occasional hearing aid fitting.

"I get a very varied, interesting case load. I get a lot of middle ear pathology. Because we're mining in SA, the deepest in the world up to 5 kilometers, we get a lot of Eustachian tube problems and therefore a lot of middle ear pathology. You see a lot of ototoxicity, multidrug resistant TB, the influence of HIV. Very interesting and very varied caseloads. (P6)

Similarly, participant P2 has a varied caseload.

"Diagnostic hearing tests. I'm not so much involved with the counselling anymore because of the language barrier. I fit aids, not on a daily basis. Yes, we do see pathology, but not so much. We see a lot of cases but the main part of it is the hearing test."

Likewise, participant P3, who is an in-house audiologist, shared her caseload:

"Well, I'm situated at the occupational house centre, so we do the hearing medicals of the employees. So, I see all the people that have shifts in hearing when we're comparing to their baseline audiogram. So, I work out then if it seems noise induced hearing loss related or whether [there] are other factors contributing to the hearing loss. And then in cases where it's serious, I do referrals to ENT specialist[s] or to general practitioners. I also see the employees or patients that have pathology, wax, ear infections. I basically manage all the patients with regards to working out what the cause might be of the hearing loss." P3

The caseload mentioned by participants does not align with scope of practice of an occupational audiologist. The context in which occupational audiologists work dictates that they should be involved in developing, organizing, and administering HCPs in consultation with other stakeholders to effectively integrate contracted services where needed to supplement the employer's resources[22,23]. Among other responsibilities, occupational audiologists are tasked with conducting programme audits and evaluations of effectiveness[23]; maintaining familiarity with Workers' Compensation regulations and trends, as well as methods of claim evaluation[24]; and the physical characteristics and methods of selecting HPDs appropriate for workplace demands and wearer needs[25]. For a detailed scope of practice for occupational audiologists, readers are referred to the report by ASHA[8].

The scope of practice of occupational audiologists extends beyond the scope of typical clinical audiology. Occupational audiologists should be in the forefront of advising companies about the auditory and non-auditory effects of noise on the health of the exposed individuals[26], as well as the effects of noise on communication and job performance[27]. Currently, the services offered by occupational audiologists in the mines in SA are not aligned with the scope of practice defined by ASHA[8].

Theme 2: Juniorizing the experts

Participants were questioned regarding their involvement in decision-making in formulating and implementing HCPs. Participants lamented that they are excluded from this process; however, they are expected to carry out certain tasks without consultation, which leads to the mining industry setting unrealistic expectations for audiologists.

"*...that's what has always been a concern really. People are making decisions about our involvement in certain things but are not involving us in the decision-making processes and that has not really stood well with me.*" (P5)

P4 stated:

"*Everyone is very... you know following the legislation around everything and its big mines we were involved with, but I was never, me as an audiologist, I was never involved or informed about the formulation or the implementation of the hearing conservation programme in the mine. However, I am expected to actively manage the workers who are exposed to excessive noise at the mines.*"

P6 lamented that audiologists' work is given to audiometrists with limited training:

"So that's also something that shocked me recently because now you will find people because of cost are taking an admin person and sending that person for 5-days training and the institution giving the certificate. The person is qualifying as an audiometrist, they are just registering at SASOHN. SASOHN is just keeping the register. They are not seeing if the person is fit to do the job or qualified to do the job as long as they have the certificate. They will put them on the register and that person is doing the testing. Someone who cannot identify pathology, cannot look into someone's ears, cannot really interpret the graph or the depth and that's how it's going. To be honest with you so it's a big challenge and this needs to be challenged. There is a lot of questions with the HCP." (P6)

These findings reveal a serious concern regarding mine management's practices when it comes to human resource protocols, as well as the expertise and scope of practice adherence. The fact that mines can assign an important health and safety role of ensuring minimisation and/or elimination of ONIHL to a non-audiologist with no accredited training in the field raises questions about the political will of the mine's management to deal with ONIHL. It also highlights a gap for the advocacy role of audiology associations in the country, as well as the regu-

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latory gap by the HPCSA. Arguably, audiometrists and occupational medical personnel may be 'competent persons' in conducting audiometric testing; however, the role of audiologists expands beyond medical surveillance. The role of audiologists begins at the conception and continues into the implementation, monitoring, and evaluation of HCPs. According to ASHA[8], although a small percentage of audiologists specialize in occupational audiology, occupational audiologists play a leading role in the hearing conservation field. These professionals bring special knowledge about hearing and communication to the OHCP team, and participate in each program component to a greater or lesser extent depending on expertise and the particular employer's needs and resources[8]. Currently, the role and importance of occupational audiologists is not fully understood in SA, and consequently occupational audiologists are occupying positions below their training and scope of practise.

Theme 3: "Audiologists [are] important ...but for what?"

Participates were asked if they felt that mines' management were aware of the audiologists' role and if they received any support from management. Responses indicated that mine management has only a superficial understanding of the audiologist's role.

"I think they understand that it is very important that there must be an audiologist. But I don't think they always understand our work. Does that make sense? In my experience, I really never had direct contact with the management". P1

P5 shared the same sentiments:

"They do understand that there's someone, but not to the extent you'd want them to. Well they do understand even though sometimes they do confuse one, but it just depends on the level of management because I have been here for long enough. Not all the managers understand what you are about, but some they understand. But some will confuse the audiologist with an audiometrist."

P7 shared a different experience.

"Well, again I'm in an ideal setting. I do get good support from management. I direct any suggestion or complaints or problems to them and they will discuss it and support where possible. I've got quite a leeway. If I say something, they support it if it makes sense. But you know, I previously worked at a big mine hospital in a bigger set-up, and I didn't have the necessary support I felt I should have had because [of] cost and time. Employees need to go back to work, that's like the main focus. You can have settings where support isn't where it should be."

Poor understanding of the role of occupational audiologists is concerning, as poor support from management has implications not only for the mining industry, but for the individuals exposed to hazardous occupational noise and the states' resources[24,25]. According to ASHA[8] occupational audiologists are important in that they advise management on many operational aspects of HCPs such as management's responsibilities and liabilities under federal, state, and local occupational health and safety regulations and Workers' Compensation statutes. Furthermore, occupational audiologists can recommend the most successful and cost-effective means of implementing each component of the program, taking into account the advantages and disadvantages of developing in-house resources versus contracting with external service providers[23]. Because occupational hearing conservationists such as audiometrists have a limited scope of practice, occupational audiologists are required to supervise OHCs[8]. In addition to the basic components of an effective HCP, occupational audiologists may be involved in forensic activities, such as serving as expert witnesses in hearing loss compensation claim cases and other forms of litigation (such as product liability)[8]. Currently in SA, the scope of practice for occupational audiologists does not reflect the roles described above, which may explain the poor understanding of the role of occupational audiologists in occupations exposed to excessive noise.

Theme 4: "Limited training in occupational audiology"

The participants were asked if their undergraduate training prepared them for their role as occupational audiologists. Only one participant, who trained in America, reported that they had received sufficient training. All participants who trained in SA stated that their training was lacking, and did not equip them with skills needed to execute their duties as occupational audiologists.

"We only had, we had one section, part of a whole thing that we had. It was a handout. It was a section of that handout. So we didn't have much training in that and we didn't have any practical training. So the knowledge I have, I accumulated after I graduated. (P4)

P7 shared a similar experience:

"It's tricky - yes and no. No in a sense that it was limited. We only did a small module on occupational audiology. It was a small project… assignment. It was the only exposure we had on occupational audiology in terms of occupational noise exposure. So we were not given information on methods to test for noise. We were not given information on how to prevent noise, what types of noise protection devices available. Yes, in a sense that we were given just a module. So we had that exposure to say there is occupational noise. It exists in terms of people getting hearing loss from work. We did a project by going to a workshop where we measured noise levels and we gave them training on how to protect their ears, but it was not with complete understanding.

P 5 highlighted the impact of not being sufficiently trained*:*

"...and the audiologist, if they are not properly trained, doesn't know all the legislation, or if they are not sure

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what is [in] Section 171. You know if the audiologist makes the mistake, it does cost the mine. It probably will cost the mine a lot of money because if that person is malingering, and that audiologist doesn't know industrial audiometry, doesn't know that I must double-check everything, make sure about the threshold and they miss that, they will probably misdiagnose the percentage and that person will be compensated. So that's one thing I felt in my training in industrial audiology. It's a big responsibility for you as an audiologist.

P1 suggested the following:

Maybe there is a space to do a postgrad in Occupational Audiology. I have not heard of that. I don't see it as a programme or certificate that can be accorded to someone obviously because the demands of our society have not been looking into that. I think it would assist a lot in managing noise induced hearing loss throughout the industries. If we can find a way to ensure that audiologists are given that skill to contribute positively, because at the current moment there isn't a positive or valuable contribution that they can make.

According to ASHA: "Ideally, all graduate audiology programs should emphasize hearing conservation by offering specialized courses and practicum experiences relevant to the skills and knowledge needed by the professional intending to work in the area of occupational hearing conservation. Audiologists-in-training should have extensive practicum experience in working on-site in an occupational setting under the supervision of an audiologist experienced in occupational hearing conservation. This practicum should include activities in all seven of the components of a model HCP"[8].

Currently in SA, there are gaps in the training of occupational audiologists, as audiologists are trained over a period of 4 years and occupational audiology is not prioritized due to the country's high burden of disease. Limited training in occupational audiology has implications for audiologists in delivering quality service in the management of occupational noise in SA.

In America, after obtaining a graduate degree in audiology audiologists interested in occupational audiology enroll for further certification to supplement their training and expand their skills and knowledge[8]. Audiologists have access to education programmes offered by professional associations such as ASHA, the National Hearing Conservation Association, and the Acoustical Society of America[8] to name a few. Some universities offer special curricula in occupational audiology to supplement their basic audiology program, with specialized courses and reference materials from other fields such as industrial hygiene, engineering, business, and public health[8]. Therefore, there is a need for local universities to evaluate their training programmes and to offer postgraduate courses to audiologists interested in pursuing a career in occupational audiology.

Conclusion

This study highlights important gaps in the role of occupational audiologists in HCPs in SA. The fact that occupational audiologists, whose scope of practice encompasses ONIHL, are only minimally and peripherally involved in developing and executing HCPs may play a significant role in the lack of progress towards the elimination of ONIHL. Locally, the audiology profession needs to deliberate on strategies to ensure that this area does not remain neglected. Professional bodies that regulate audiology and occupational health need to work together to ensure systematic and efficient provision of services to this part of the population. Additionally, universities training audiologists need to review their curricula to ensure that occupational audiology is afforded the same attention as other aspects of audiology.

Limitations and Suggestions for Further Research

These findings should be considered with an awareness of the limitations of the study. Firstly, the small sample size, which was recruited through snowball sampling, restricts the ability to generalize these findings beyond the study sample. Future research on a larger representative sample, perhaps on audiometrists involved in HCPs in South African mines, may allow the issues uncovered in this study to be further explored. Additionally, confirmation and direct observation of practice through ethnographic studies is required.

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Appendix J: Article 4: Occupational noise induced hearing loss in the mining sector in South Africa: Exploring Hearing Conservation Programmes as complex interventions embedded in a realist review approach



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Occupational noise-induced hearing loss in South African large-scale mines: exploring hearing conservation programmes as complex interventions embedded in a realist approach

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Background. Complex interventions have been conducted in the field of public health to improve health at the individual, organizational policy or population level. In occupational audiology, hearing conservation programmes (HCPs), which are interventions to minimize or eliminate occupational noise-induced hearing loss, are currently not defined as complex interventions, despite them fitting the definition and features of complex interventions. Therefore, this study aimed to explore whether HCPs are a complex intervention, fitting the predefined criteria for complex interventions. *Method*. A qualitative, descriptive research design was conducted using three sources of data – document analysis, interviews and systematic review – to allow for triangulation. Data were collected through purposive sampling and qualitative content analysis was used. *Results*. This study confirmed that HCPs are a complex intervention founded on solid and consolidated theories. Therefore, these results paved the way for realist reviews to be conducted in the mining sector in South Africa in order to understand the mechanisms influencing the success or failure of HCPs locally. *Conclusion*. The success of HCPs in the mining sector depends on conducting contextually evidence-based evaluations such as realist reviews which can provide policy-makers with contextual evidence for why certain programmes do or do not work in certain settings.

Keywords: Hearing conservation programmes; complex intervention; realist reviews; occupational noise exposure; mining industry; South Africa

1. Background

In South Africa, hearing conservation programmes (HCPs) have been formally in existence for over two decades, since the declaration of the 1996 Mine Health and Safety Act [1]. In 2003, the Mine Health and Safety Council (MHSC), comprising state, employer and labour representatives, circulated the 2003 MHSC milestones on the elimination of occupational noise-induced hearing loss (ONIHL) in the mining industry with an aim to achieve these targets by 2014. These 2003 MHSC milestones [2] had two targets. The first target stated that by December 2008, HCPs implemented by the industry must ensure that there is no deterioration in hearing greater than 10% amongst occupationally exposed individuals. The second target focused on the noise source, and stated that by December 2013, the total noise emitted by all equipment installed in any workplace must not exceed a sound pressure level of 110 dB(*A*) at any location in that workplace (including individual pieces of equipment) [2].

When the aforementioned milestones were evaluated at the end of 2013, it became apparent that the mining industry had not met all of the targets. Therefore, the 2003 milestones were revised. The revision of the 2003 milestones saw refinement and more specificity in the targets, which made the milestones seem more measurable. Firstly, as far as deterioration in hearing is concerned, the new target specifies that by December 2016, no employee's standard threshold shift (STS) will exceed 25 dB from baseline when averaged at 2000, 3000 and 4000 Hz in one or both ears. Secondly, regarding the noise source, the revised milestones state that by December 2024, the total operational or process noise emitted by any equipment must not exceed a milestone sound pressure level of 107 dB(*A*) [3].

A close look into these milestones revealed that a significant flaw is evident in them. This flaw could arguably be the key reason for the failure of the South African mining industry to meet the targets. Firstly, the targets focus on only two aspects of noise conservation; hearing deterioration and noise source. These two aspects are the responsibility of mine management. A key stakeholder, the mineworker, has not been included in the targets at all. One could argue that education of and buy-in from the mineworkers with regards to hearing conservation is key to the success of any intervention involving the miners. Therefore, careful deliberation should occur around the role of mineworkers in the setting of targets, if HCPs are to succeed. Secondly, the sequencing of the two targets (hearing deterioration and noise source) appears incongruent to the goal. Reduction of noise from the noise source

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should come prior to the expectation of reducing the deterioration of hearing loss. These milestones, as currently stated, appear to expect the opposite. That is, there must be a reduction in deterioration of hearing loss in miners at least 5–8 years before the reduction in the level of intensity of the noise source causing the hearing loss. Lastly, the 2014 milestone revisions, which acknowledged the failure to meet the 2003 milestones, increased the time frame of reducing noise from the noise source from 5 to 8 years. This seems to indicate serious challenges with this target, which the current author believes is key towards eliminating ONIHL.

Challenges in meeting milestones have implications for ONIHL within the South African mining industry. For instance, in 2013, statistics on ONIHL as recorded by the Department of Mineral Resources indicated that, on average, 1600 cases of NIHL are reported each year [4]. An unpublished study aimed to understand stakeholders' perceptions of the HCPs implemented in the South African mining industry. This study sought to understand the reasons leading to the revision of the 2003 MHSC milestones. Findings of this study highlighted challenges with the implementation of the 2003 MHSC milestones. These challenges included poorly defined action plans, lack of cohesive engagement and collaboration with all stakeholders; with exclusion of some stakeholders, from formulation to implementation of these milestones. These challenges raise important implications for the success of any intervention programme.

Current evidence suggests that HCPs implemented in the South African mining industry are currently not achieving the desired results. It is the author's belief that studies conducted on the presence and management of ONIHL in the mining sector will continue to yield the same unsatisfactory results if careful strategic and contextually relevant changes that adopt realist reviews within a complex intervention position are not considered.

There are therefore calls for new, innovative and evidence-based ways of managing excessive exposure to hazardous noise in the mining industry. There is a need for approaches that will focus on holistically understanding why HCPs are not successful in the South African mining industry, while their counterparts in developed countries have reported success. One such approach is a realistic review of the HCPs currently implemented in the South African mining industry.

Realist reviews are fundamentally concerned with 'understanding and unpacking the mechanisms by which an intervention works (or fails to work)' [5,p.1]. Realist approaches focus on theory development while taking into consideration the context when methodically and transparently synthesizing results [6–8]. A realist review, although a relatively new methodological strategy [7], can assist in explaining why HCPs implemented locally are currently failing to achieve the set targets. Benefits of conducting realist reviews include, firstly, providing stakeholders and policy-makers with enlightenment and empirical evidence on the nature of the programme or intervention implemented in a given setting [7]. Secondly, realist reviews assist policy-makers to interpret and clearly understand why a programme worked better in one context than another, e.g., international vs local context. Thirdly, realist reviews provide policy-makers with a justification for taking one course of action over another. Lastly, realist reviews alert policy-makers to potential problems and specific measures that can be applied to mitigate potential problems. Moreover, realist reviews provide explanations rather than judgements around interventions [7].

Realist reviews are conducted to review complex interventions [9–13]. Complex interventions are defined as interventions built from multiple interacting components, which may act both independently and interdependently [14,15]. These components may include behaviours, behaviour parameters and methods of organizing those behaviours, and they may have an effect at an individual level, organizational level or population level [16]. Complex interventions are generally conducted to improve health either at the individual, organizational policy or population level in different fields such as public health research, medical research [14] and any public services dealing with complex social interventions such as performance measures, regulations and inspection or funding reforms [7].

In the field of occupational audiology, complex interventions have not been conducted even though research widely demonstrates both the auditory and non-auditory health impacts of excessive exposure to occupational noise in the workplace [17–20]. Furthermore, the fact that HCPs are 'built from multiple interacting components, which act both independently and interdependently' [21,p.1281] from each other makes, them well suited to complex interventions. Hence, the current study aimed to explore whether HCPs are a complex intervention, fitting the predefined criteria for complex interventions described by Pawson et al. [7] as follows:

- Complex interventions are theories.
- Complex interventions are active and able to achieve their effect through the active involvement and engagement of individuals.
- Complex interventions are comprised of long journeys.
- Complex interventions are non-linear in their implementation chains, and can even go into reverse.
- Complex interventions are fragile and embedded in multiple social systems.
- Complex interventions are prone to be borrowed.
- Complex interventions are open systems that feed back on themselves.

2. Methodology

2.1. Research strategy

A qualitative, descriptive research design was adopted as this study used existing data to explore the complexity of HCPs. A qualitative descriptive approach was selected because of its cardinal features. Firstly, it allows the use of a range of theoretical orientations. Secondly, it allows the use of any purposive sampling technique. Thirdly, it allows the use of document reviews and semi-structured interviews to collect data. Fourthly, it allows the use of content analysis as an analysis technique. Lastly, it allows the provision of a descriptive summary organized in a way that best fits the data [22,23]. All of these aforementioned features were adopted in the current study.

2.2. Sampling strategy

Purposive sampling was utilized in this study as it allowed the researcher to use the data previously collected and readily available to the researcher. Data were obtained from three sources: (a) interviews with stakeholders in the South African mining sector; (b) document analysis of the regulations on ONIHL in South African mines; (c) a literature review of original research on the management of ONIHL in the mining sector. Therefore, the use of purposive sampling was ideal in that it allowed the research, according to Etikan et al. [24], to identify and select individuals and groups of individuals who have experience and are knowledgeable on the management of ONIHL in the mining industry. Furthermore, the researcher sought to recruit participants who are available and willing to participate in the current study. Also, the researcher used documents that are readily available online.

2.3. Sources of data

2.3.1. Interviews with various stakeholders

The first source of data was obtained from interviews conducted with 15 stakeholders who are involved in the management of ONIHL in the South African mining sector. These participants consisted of audiologists, ventilation and occupational health engineers, occupational hygienists and representatives of the state, labour and employer. These participants were identified from the websites of the companies affiliated with the mining industry. Participants were contacted by telephone and via email to request them to participate in the study. The interviews were conducted both face to face and by telephone, depending on the availability of participants. Interview questions were formulated by the researcher and focused on the specific roles of the participants, the objectives of the mining industry with regard to the management of ONIHL and the challenges and progress since the formulation to the evaluation of the HCPs in the mining sector.

2.3.2. Document analysis

The second set of data was obtained through the document analysis of the Acts, regulations, policies and guidelines on the management of ONIHL in the South African mining sector since 1994. Websites of the companies affiliated to the mining industry were searched for the aforementioned documents. The search yielded eight documents (Table 1) which accurately focused on the complexity of HCPs in the mining sector. Documents included and analysed in this study were from 1994 to date with a focus on occupational health and safety in the mining industry in South Africa.

2.3.3. Systematic review

The last set of data emerged from a systematic review of literature on the management of ONIHL in the African mining industry. The literature search yielded nine articles that met the inclusion criteria. Of the nine articles, seven were conducted in South Africa while, of the remaining two, one was conducted in Ghana and the other in Zimbabwe. Therefore, seven articles (Table 2) from the South African mining sector were included in the final sample.

Table 1. Document analysis data.

Document number	Name of document	Year promulgated	Reference
1	Report of the Commission of Inquiry into Safety and Health in the Mining Industry	1994	[25]
2	Mine Health and Safety Act, 1996: No. 29 of 1996.	1996	[1]
3	South African Mining Industry Journey to Zero Harm 2003–2013	2014	[26]
4	Audiometry in the Work Place	2011	[27]
5	Noise-induced Hearing Loss Regulations	2003	[28]
6	Guideline for the Compilation of a Mandatory Code of Practice for an Occupational Health Programme (Occupational Hygiene and Medical Surveillance) for Noise	2003	[29]
7	Guidelines for Hearing Conservation Programmes	2003	[30]
8	(2014 mine Occupational Health and Safety Summit) Every Mine Worker Returning from Work Unharmed Every Day: Striving for Zero Harm	2014	[31]

Table 2. Systematic review articles.

Author(s) (year)	Research title	Reference
Edwards et al. (2015)	Evaluation of the Current Practices of Noise-induced Hearing Loss (NIHL) Awareness Training in the South African Mining Industry	[32]
Gumede et al. (2014)	Strategy Towards a Mining Industry-wide Buy-and-Maintain Quiet Initiative to Reduce Noise Induced Hearing Loss	[33]
Ntlhakana et al. (2015)	The Use of Hearing Protection Devices in South Africa: Exploring the Current Status in a Gold and a Non-ferrous Mine	[34]
Steenkamp (2008)	A Personal Approach to Hearing Conservation: The Key to Effective Second-level Noise Control	[35]
Amedofu (2007)	Effectiveness of Hearing Conservation Programme at a Large Surface Gold Mining Company in Ghana	[36]
Mutara and Mutanana (2015)	An Analysis of a Hearing Conservation Programme (HCP) at a Mining Company in Zimbabwe	[37]
Steenkamp (nd)	A Six Sigma-based Management Model to Eliminate the Noise-induced Hearing Loss Pandemic in South African Mines	[38]
Rashaad Hansia and Dickinson (2010)	Hearing Protection Device Usage at a South African Gold Mine	[39]
Burger et al. (2004)	Design and Development of a Low Noise Rockdrill	[40]

These articles were from 1994 and had a focus on the management of ONIHL in the mining industry.

2.4. *Ethical considerations*

The author declares that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guidelines on human experimentation. Ethical approval was obtained from the University's Medical Ethics Committee (Protocol number M160264). Participants were informed regarding confidentiality, anonymity and the right to withdraw from the study without any negative consequences to the participants.

2.5. *Trustworthiness*

Trustworthiness and credibility of the findings were achieved through triangulation as three sets of data were used in this study. Triangulation allowed for the collaboration of findings across different sets of data, thereby reducing the impact of potential biases that can exist in a single study [41]. Furthermore, since the researcher is an audiologist, to guard against any bias towards the findings of the study, the researcher used a peer reviewer.

2.6. *Data analysis*

A qualitative content analysis approach was adopted as it allowed for a systematic and objective means to make valid inferences from verbal, visual or written data in order to describe and quantify specific phenomena [42]. Deductive content analysis is used in cases where the researcher seeks to retest existing data in a new context in order to test categories, concepts, models or hypotheses [43]. Therefore, this study adopted a deductive content analysis method recommended by Elo and Kyngäs [43], namely developing a structured analysis matrix, data coding according to categories and hypothesis testing and correspondence comparison to earlier studies. Results were then presented in line with the features of complex interventions as described by Pawson et al. [7].

3. Findings and discussion

Typically, in qualitative content analysis, supporting evidence is presented in the form of quotations, excerpts, quotation and passages as recommended by Labuschagne [44]. However, in this current study, the findings are summarized as some of the excerpts are lengthy, Readers will be directed to where they can find the full document should they require the original full text.

3.1. *Feature 1: complex interventions are theories*

According to Pawson et al. [7], complex interventions are based on hypotheses that are causal in nature. This statement implies that, e.g., if a certain evidence-based programme is implemented, specific results are expected. According to Document 1, entitled 'Report of the Commission of Inquiry into Safety and Health in the Mining Industry' [25] (Table 1), HCPs were implemented in the South African mining industry post a lengthy deliberation among various stakeholders who were tasked with addressing the challenge of poor occupational health and safety in the workplace. Consequently, the 2003 MHSC milestones and the revised 2014 milestones were implemented to eliminate occupational noise in the mining industry as detailed in Documents 1 and 2 [25,1] (Table 1). It is therefore clear that implementing the MHSC milestones was a move towards the elimination of ONIHL. It can therefore be argued that the implementation of MHSC milestones

was informed by the hypothesis that if HCPs, through the milestones, are implemented, then elimination of ONIHL can be achieved. Therefore, this assertion serves as the causal hypothesis or theory supporting the implementation of HCPs in the South African mining industry in order to protect the health and safety of persons at the mines. This finding is in line with that of Pawson et al. [7], who concluded that interventions are theories based on a hypothesis which postulates that if one delivers a programme in this way or one manages services in this manner, then this will bring about some improved outcome. Therefore, this postulation is in line with the premise that if the mining industry implements HCPs taking into account the context of the mine, it is possible to eliminate excessive noise exposure in the mines and thereby achieve the desired outcome. Furthermore, findings from the systematic review also support the importance of having a solid and consolidated theoretical plan when implementing HCPs as a failure to have a solid and consolidated foundation can negatively influence the success of HCPs.

3.2. *Feature 2: complex interventions are active*

Complex interventions are active, meaning that they achieve their effects through active participation and input from various stakeholders involved in that particular programme. Authors such as Craig et al. [45], Brown et al. [46] and Hawe [47] view complex interventions in terms of how interventions work, meaning what are the active ingredients components of the programme and how these ingredients exert their effect. Brown et al. [46] list three important ingredients or components of active complex interventions: (a) active components assist in raising awareness of the key issues in the choice of intervention preferred; (b) active components improve the knowledge pertinent to decision-making; (c) active components provide preparation for the involvement of various stakeholders in the consultation.

To highlight these components, the same document [25] (Table 1) reveals that the mining industry is aware of the consequences of unmanaged excessive noise in the workplace, hence the implementation of HCPs through the 2003 and 2014 MHSC milestones as the intervention of choice. The following statement supports these findings: ‘the mining industry is not making the desired progress with noise-induced hearing loss, which is a major occupational health concern. As an industry, we have committed to the massive reduction and elimination of occupational noise induced hearing loss’ [4,p.1]. With regard to improving the knowledge pertinent to decision-making and involvement of stakeholders in consultations, Document 3 [48] entitled ‘South African Mining Industry Journey to Zero Harm from 2003–2013’ (Table 1) reveals that ‘The road to attaining Zero Harm is a long, winding and bumpy one. However, it is a road that is walked alongside diverse people collaborating, executing plans and strongly rallying around a common objective’ [26,p.9]. From this excerpt, arguably, the stakeholders involved in the formulation and implementation of HCPs in the mining sector have engaged and collaborated with different stakeholders in order to select the best and evidence-based intervention to eliminate noise in the mining industry. Data obtained from various stakeholders also confirmed continual collaboration and consultation of different stakeholders depending on the task at hand.

3.3. *Feature 3: complex interventions are comprised of long journeys*

Complex interventions have long journeys, meaning they begin in the heads of policy architects, pass into the hands of practitioners and managers, and (sometimes) into the hearts and minds of the end users [7]. As alluded to in the previous section, this feature speaks to the effect that interventions are typically a long process from conceptualization to evaluation. Holmboe [49,p.351] states ‘the journey to change takes time’. This was evident in this study as findings from Document1 [25] (Table 1) revealed that before the formalization of HCPs in South Africa, the then President of the country appointed a task team, referred to as the Leon Commission, to address health and safety concerns in the mining industry. Through deliberations of this committee, a Mine Health and Safety Act 29 of 1996 [1] was established to provide a comprehensive legal framework for creating a healthy and safe working environment. Subsequently, in 1997, the MHSC was established and led the development of the 2003 MHSC milestones on eliminating ONIHL. These milestones underwent the Presidential health and safety audit in 2008 and were ultimately revised in 2014.

The findings presented clearly illustrate the journey and process that was undertaken to formally implement HCPs in the mining sector. In addition, it is clear that the idea of introducing HCPs in the mining sector started with the President, and this idea was passed on to various stakeholders and, eventually, the stakeholders who implemented the milestones were not necessarily the individuals who developed the milestones themselves. Furthermore, data obtained from the interviews also highlighted the same sentiments reported in Document 3, entitled ‘South African Mining Industry Journey To Zero Harm 2003–2013’ [26] (Table 1), and indicate that the process was in progress when these stakeholders were roped in and that the process is still continuing, hence the latest milestones will be evaluated in 2024. The length of time it has taken for the conceptualization, implementation, evaluation and revision of milestones appears to be significantly long. The process from formulating to evaluating the HCP journey in the South African mining industry has taken a long journey, whose end may not be near. However, it is hoped that this journey brings out the desired outcome.

3.4. *Feature 4: complex interventions are non-linear in their implementation chains*

According to Pawson et al. [7], complex interventions are non-linear and can even go into reverse. Complex interventions are built from multiple interacting components, which may act both independently and interdependently, and include behaviours, behaviour parameters and methods of organizing those behaviours, and they may have an effect at an individual level, organizational level or population (local society) level [16,17]. It is therefore no wonder that complex interventions are non-linear and they may even go into reverse. This was evident in this current study as data obtained from Document 2, entitled 'Mine Health and Safety Act, 1996: No. 29 of 1996. Mine and Health Safety' [1] (Table 1), revealed that, initially, the 2003 MHSC milestones were concerned with the eliminating ONIHL by focusing on monitoring the percentage of hearing loss (PHL). However, with further consultation and involvement of other stakeholders along the way, the focus council changed from using PHL to monitoring the STS. Hence, the milestones were revised to incorporate the changes identified by the stakeholders. Furthermore, the initial milestones also targeted limiting total noise emitted by all equipment installed in any workplace not to exceed a sound pressure level of 110 dB(*A*) at any location in that workplace (including individual pieces of equipment). Through consultations and studying the progress from developed countries such as Canada, noise emission was then reduced further to 107 dB(*A*). These findings attest to the importance and the impact of continual engagement among stakeholders in order to improve HCPs in the mining sector.

3.5. *Feature 5: complex interventions are fragile*

Complex interventions are fragile creatures, and are often embedded in multiple social systems. Furthermore, complex interventions are rarely, if ever, equally effective in all circumstances because of the influence of context [7]. The observation that complex interventions are rarely equally effective in all situations due to contextual factors was evident in this study. For instance, in this current study, interviews with stakeholders revealed that some mines were able to meet the targets while others were unable to meet these milestones. The scales (large vs small) of the mines, the culture of the mines and the active involvement of stakeholders were cited as some of the factors that influence the success of the milestones. Therefore, the size of the mine and the availability of resources and level of support and commitment from all stakeholders may contribute to the fragility of the implemented programmes. Furthermore, social systems have an impact on the success of programmes, therefore having a buy-in from all departments and systems is crucial in the success of HCPs. As already mentioned, social systems may influence the outcome of implemented interventions. Therefore, it is important to consider social systems and their impact on the programme. For instance, from the interviews conducted and systematic review results, the role of mineworkers in the management of ONIHL was not overtly communicated. It is important to include mineworkers as they are directly exposed to the noise, and their participation and buy-in may be a critical step in achieving the desired outcomes.

3.6. *Feature 6: complex interventions are prone to be borrowed*

Complex interventions are leaky and prone to be borrowed. Pawson et al. [7] state that, when it comes to putting flesh on the bones of an intervention strategy, practitioners will consult with colleagues and cross-fertilize ideas. In engaging with various stakeholders, it is important to acknowledge that 'transparent and meaningful consultation with key stakeholders is a cornerstone of informed decision-making and good governance' [50,p.1]. Consultation allows for cross-fertilization of ideas and knowledge which influences stakeholders on communal decision-making by allowing stakeholders to communicate their individual knowledge to other stakeholders in order to reach a mutual decision to execute the cross-fertilized idea that is best suited in accomplishing a given task [51]. In the current study, the consultation and the cross-fertilization of ideas was evidenced by engaging various stakeholders with an aim of implementing evidence-based interventions. Therefore, in this study, the initial MHSC milestones were focused on and concerned with PLH shifts as opposed to the STS. Through consultation and further engagements with other stakeholders, the milestones were revised to focus on the STS as it was rationalized that this was the best strategy to monitor and thereby eliminate ONIHL in the mining sector. The following quotation from one of the stakeholders who participated in the interview summarizes the process:

> For instance, when we were working towards the 2014 milestones, the new milestones, then we got in an audiologist you know because we were debating for instance, should we use the PLH (percentage of hearing loss) shift or should we use the STS (standard threshold shift) as a way of early detection of noise. So an audiologist from an academic institution was invited and she went through the cons and the pros and in the end, we are agreed as the industry that we will shift from PHL shift to STS. So that's what the new milestones are based on STS.

This quote highlights the importance of consultation and cross-fertilization of ideas. Through the engagement of stakeholders, opportunities to improve the quality of HCPs in the mining industry were realised. Document 3 also supports the importance of collaboration: 'The following aspects are critically important to reach the target of Zero Harm: the right mind set, correct action and strong support from stakeholder. Working together, the South African mining industry has achieved major successes' [26p.5]. Having a common goal and allowing for consultations

and interrogation of ideas will indeed yield favourable outcomes.

3.7. *Feature 7: complex interventions are open systems that feed back on themselves*

The final feature of complex service interventions is that they are open systems that feed back on themselves. As interventions are implemented, they change the conditions that made them work in the first place [7]. According to Cooper et al. [9], complex interventions do not act as independent agents for change; rather, they operate within open systems, interacting with personal, interpersonal and environmental factors outside of the programme. Complex interventions are multifactorial systems which are interconnected, changes in one part of the system feed through other parts of the system and feed back on themselves [21]. Therefore, learning occurs that alters subsequent receptivity to interventions, which ultimately leads to unintended effects in the longer term [7]. Data from the current study indicated that HCPs are manipulated or affected by factors outside the programme itself. For instance, due to poor socio-economic status and low wages for mines, some stakeholders revealed that some workers expose themselves to excessive noise in the workplace in order to be compensated for incurring a hearing loss in the workplace. Other stakeholders expressed that most mines use production incentives for production, therefore, some workers may expose themselves to excessive noise in order to meet the production targets and get a bonus. This revelation by stakeholders also highlighted the importance of educating the workers about the long-term effects of exposure to excessive noise in the workplace.

4. Conclusion

The aim of this study was to explore whether HCPs are a complex intervention, fitting the predefined criteria for complex interventions described by Pawson et al. [7]. The analysis of documents, systematic reviews and interviews from stakeholders provides evidence for the complexity of HCPs currently implemented in the South African mining industry.

The findings revealed that HCPs are, firstly, based on a theoretical premise which states that implementation of HCPs will bring about the elimination of ONIHL in the mining industry. Secondly, formulating, implementing monitoring and evaluating HCPs involved participation of various stakeholders, thus making them active complex interventions. Thirdly, HCPs were formulated in 1994 and are still ongoing, thereby making them complex interventions with long journeys. Fourthly, HCPs comprised multiple pillars, which act both independently and interdependently; hence, making them non-linear complex interventions. Fifthly, HCPs are influenced by the context, such as the size of the mine, the resources available and the culture of the mine, thereby making them fragile complex interventions. Sixthly, the implementation of HCPs has been influenced by continual consultation and cross-fertilization of ideas, therefore making them complex interventions prone to being borrowed and refined. Lastly, HCPs are affected by personal, interpersonal and environmental factors outside of the programme, thereby making them open systems that feed back on themselves.

Much energy and dedication has been fuelled towards achieving the best outcomes; however, the outcomes are still not satisfactory. It is clear that the journey towards elimination of ONIHL in the mining sector is still far from being over. There is therefore a need for the mining industry to focus its energies on new and innovative ways of understanding why some aspects of the HCPs currently implemented yield desired outcomes while some do not. There is therefore a need to implement studies focusing on the context of each mine so as to improve HCPs in individual mines as opposed to implementing a HCP for all mines as a blanket approach.

Failure to recognize HCPs as complex interventions has implications, not only for the individuals exposed to noise, but for their colleagues, families, companies and the state at large. Arguably, exposure to excessive noise is not life threatening; it is, however, health threatening. Therefore, there is an urgent need to recognize HCPs as a complex intervention in order to conduct a realist review on the status quo of noise management in South Africa as a developing country.

In conclusion, the findings of this study have shown the complexity of HCPs, which was a necessary step in moving towards embarking on conducting realist reviews in local mines to understand what works for which mine under what conditions. Therefore, current findings pave the way for mines to conduct realist reviews, now that it has been confirmed that HCPs are complex interventions needing realist reviews to understand their mechanisms.

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Appendix K: Condensed Proposal for the mining sector

SPEECH PATHOLOGY & AUDIOLOGY
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Occupational Noise Induced Hearing Loss in South African Large Scale Mines: From policy formulation to implementation and monitoring

Summary of the study

Hearing loss resulting from excessive exposure to noise in the workplace (occupational noise induced hearing loss -ONIHL) is a documented concern in the mining industry. Research shows that this kind of hearing loss is classified as a leading work-related disability, followed by hearing loss caused by old age (presbycusis); and that it has severe consequences for the individuals exposed to high levels of noise in the workplace (Ritzel & McCrary-Quarles, 2008). In 2007, the Department of Mineral Resources (DMR) reported that there were 1820 cases of ONIHL in the South African mines (Presidential Mine Health and Safety Audit, 2008). Lonmin (2012) reported 35 per 1000 cases of ONIHL in their 2011/2012 annual report; while Anglo American Platinum reported 46 per 1000 cases in the 2010/2011 financial year. In 2013, the Department of Mineral Resources reported that, on average, 1600 cases of ONIHL are reported annually (Balfour-Kaipa, 2013). In 2014, the South African Mine and Health Safety Council reported ONIHL as one of the most prevalent work-related hazards affecting miners in the country (Chamber of mines, 2014).

Potentially, ONIHL may negatively interfere and compromise communication among workers; which may lead to safety challenges as workers may not be able to hear warning signs such as sirens while performing their duties. This may also impact on their ability to perform or complete tasks that are dependent on verbal communication. This may lead to a communication handicap as workers may be seen as incompetent or inactive, which ultimately will impact on team

work and group productivity (Momm & Geiecker, n.d). Compromised ability to communicate may lead to increased risks of accidents (Kirchner et al., 2012). Moreover, ONIHL can present a limitation on the kind of employment suitable for a person with a hearing loss (P. R. Thorne, 2006); which may then possibly lead to economic burdens for developing countries in particular. Furthermore, due to hearing loss sustained during the employment tenure, the mining industry has to compensate the employees for occupational injuries. Approximations by Rand Mutual Assurance (RMA), are that, of the 340000 miners ensured under the RMA, 50000 were compensated for occupational injury annually. Specifically, 12% of these claims are reported to have been solely for occupational noise induced hearing loss (Beagle, 2004). However, the figures published by the Mine Health and Safety Council in 2003 were higher than the figures published by RMA.

Storbeck (n.d.) argues that hearing loss represents a heavier burden in developing countries than in developed regions of the world because of the challenges faced by developing countries. Reportedly, low socio-economic status and poor working conditions in the mines have led to the high prevalence of tuberculosis (TB) in the mining sector, especially in sub-Saharan Africa (Stuckler, Basu, McKee, & Lurie, 2011).

In fact, Stuckler et al. (2011) postulate that miners in the sub-Saharan African region have the greatest prevalence of TB worldwide. The incidence of TB is reported at 3000–7000 per 100000 miners per year in some areas. Stuckler et al. (2011) further assert that the prevalence of TB in the mining population is projected to be as much as ten times higher than in the populations from which the miners originate from. Furthermore, these authors approximate that miners are three to four times more likely to be infected with HIV compared to non-miners (Stuckler et al., 2011). The co-infection with HIV/AIDS and TB indicates that affected miners may be on treatment for HIV/AIDS and/or TB. Studies on the audiological function of adults with TB/HIV/AIDS predict that people on treatment for TB/HIV/AIDS; if exposed to continuous and prolonged excessive noise in the workplace, are at a greater risk of clinical hearing loss due to the synergistic effects of the two toxins (noise and ototoxic medications) on the ear (Khoza-Shangase, 2010). This co-occurrence of TB and HIV/AIDS and noise exposure may increase and worsen the prevalence, onset and progression, nature, as well as the degree and the configuration of occupational noise induced hearing loss in this population (Khoza-Shangase, 2010).

Problem statement

With all that is known about noise exposure and its effects on the individuals exposed to noise, the mining industry and the country at large; the incidence of occupational noise induced hearing loss in the mining industry is still increasing. According to Balfour-Kaipa (2013, pg.1), the Chamber of Mines is "not making the desired progress with noise-induced hearing loss, which is a major occupational health concern". It should be noted that the increase in occupational noise induced hearing loss in not due to lack of interest from the mining industry in combating this challenge. In actual fact, evidence suggests that there has been an interest in managing noise in the industry. Hearing Conservation Programmes (HCPs), policies, regulations, Occupational Health and Safety Summit Milestones and studies have been conducted in the mines in order to address this concern. However, published studies conducted to evaluate the effectiveness of these measures indicate that the management or the elimination of noise in the mining industry has not been successful. However, the industry itself is committed to "the massive reduction and elimination of occupational noise induced hearing loss" (Balfour-Kaipa, 2013). Furthermore, Balfour-Kaipa farther states that ONIHL is "prominent in the mining industry because action plans aimed at eradicating this disease are not as well integrated as they should be. We need far more comprehensive noise-control programmes" (Balfour-Kaipa, 2013).

There is therefore a need for studies to be conducted in the mining industry which look into the management of noise comprehensively and holistically. The proposed study will seek to understand the management of noise in the mining industry from policy conception to the implementation, evaluation and monitoring of HCPs in the mines. Furthermore, each and every pillar of the HCP should be addressed individually to ascertain how it is implemented, evaluated and monitored. Also, there is a need for studies that will include the stakeholders in the mining industry. The importance of the involvement of the stakeholders cannot be over emphasized. The current study therefore was conceptualised within this context.

Benefit of this study to the mining industry

1. This study seeks to understand and describe the management of occupational noise induced hearing loss in the mining sector from when the policies as well as milestone are developed

to when they are implemented, evaluated and monitored in the mining industry. The study seeks to understand what informs the need for these policies and milestones, as well as to establish the role and the responsibilities of the different stakeholder involved in the formulation to monitoring of these policies. Challenges and opportunities encountered at each stage from formulation to monitoring will be documented. Understanding this process from formulation to monitoring will assist in highlighting areas that may need attention when devising and implementing HCPs.

2. This study also seeks to understand and describe HCPs implemented at various mines in the mining industry. Each pillar will be addressed to understand the role it plays in the management of noise in the workplace, as well as its effectiveness. Most studies have focused on engineering controls, personal protection devices, and audiometry; while neglecting the other core aspects of HCPs. Furthermore, a number of studies have focussed on aspects individually, without attempting to holistically formulate a comprehensive picture of HCPs within the identified context.
3. This study will also endeavour to predict the prospective outcomes of hearing loss in individuals exposed to high levels of noise, using a noise management matrix to calculate their exposure and recommending a suitable intervention programme for those individuals. If this matrix is used appropriately, it will assist in bringing down the costs incurred by the mining industry in compensations. Furthermore, the individual results may be applicable to a homogenous exposure group that the individual may be part of.

Specific objectives:

1. To review current regulations, Acts, and policies regarding occupational noise-induced hearing loss in the South African mines.

    - Conduct online searches to retrieve policies, regulations and Acts and annual reports pertaining to the management of occupational noise induced hearing loss in the mining sector

- Requesting mines/Chamber of Mines/Mines Health and Safety Council for access to their policies, regulations, Acts and annual reports that are in place to address and manage occupational noise induced hearing loss in the specific mines

2. To establish the extent to which these policies, Acts and regulations are observed, and/or implemented in HCPs in specific mines

    - Conduct interviews with different stakeholders in the mining industry such as the Mines Health and Safety Council (State, Employer, and Labour representatives), Occupational Health and Safety officers, Hygienists, mines managers, audiologists, unions, ground workers. These interviews will focus on the implementation, evaluation and monitoring of HCPs implemented in the specific mines. All the pillars of the HCP will be investigated.

    - Measurements of noise levels will be conducted to ascertain the noise levels emitted by the equipment at specific mines. The noise measurements will be conducted in line with the revised 2014 milestones

    - Conduct retrospective record review audiograms at different mines to document the past trends with regards to degree of hearing loss sustained by individuals, as well as to determine if the rate of compensation claims have increased, decreased or stayed the same since 2003. The retrospective review of audiograms is also in line with the revised 2014 milestones

    - Observation to document the practices and behaviours of individuals exposed to noise in the workplace. A checklist will be utilized to record individual's behaviours, the presence of warning signs when approaching noisy areas and the use of hearing protection devices when using noisy machinery or working in noisy environments.

3. To explore factors influencing implementation of HCPs

    - Conduct interviews with different stakeholders in the mining industry such as the Mines Health and Safety Council (State, Employer, and Labour representatives), Occupational Health and Safety officers, Hygienists, mines managers, audiologists,

unions, ground workers. These interviews will focus on the barriers and facilitators contributing to the success of hearing conservation implementation at various mines.

- Information from the policies, regulations, Acts and annual reports will be used to obtain this information.

4. To predict the outcome of the trends status of miners exposed to excessive noise when compared to a homogenous exposure group in the next 5 to 10 years.

    - Based on the baseline audiograms, using the standard threshold shift, the noise exposure in dBs a person is exposed to, calculate/ predict the trend in the hearing of the exposed individual. This prediction will take into account the age, gender and the medical status (individuals on ototoxic/TB medication) of each individual.
    - Using a noise management matrix, predict the prospective trends in individuals considered to be at high and medium exposure levels. 2 calculations with be conducted:
        1. Prediction with the use of HCP
        2. Prediction without the use of HCP

Ethical Considerations

Ethical clearance has been obtained from University of the Witwatersrand Human Research Ethics Committee (Medical); clearance certificate number: M160264. The details and the identity of all the stakeholders and mines participating in this study will be kept confidential. There are no research-related risks in participating in this study and participation is completely voluntary. If participants decide not to participate or withdraw from this study at any time, they are free to do so and it will not be held against them.

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