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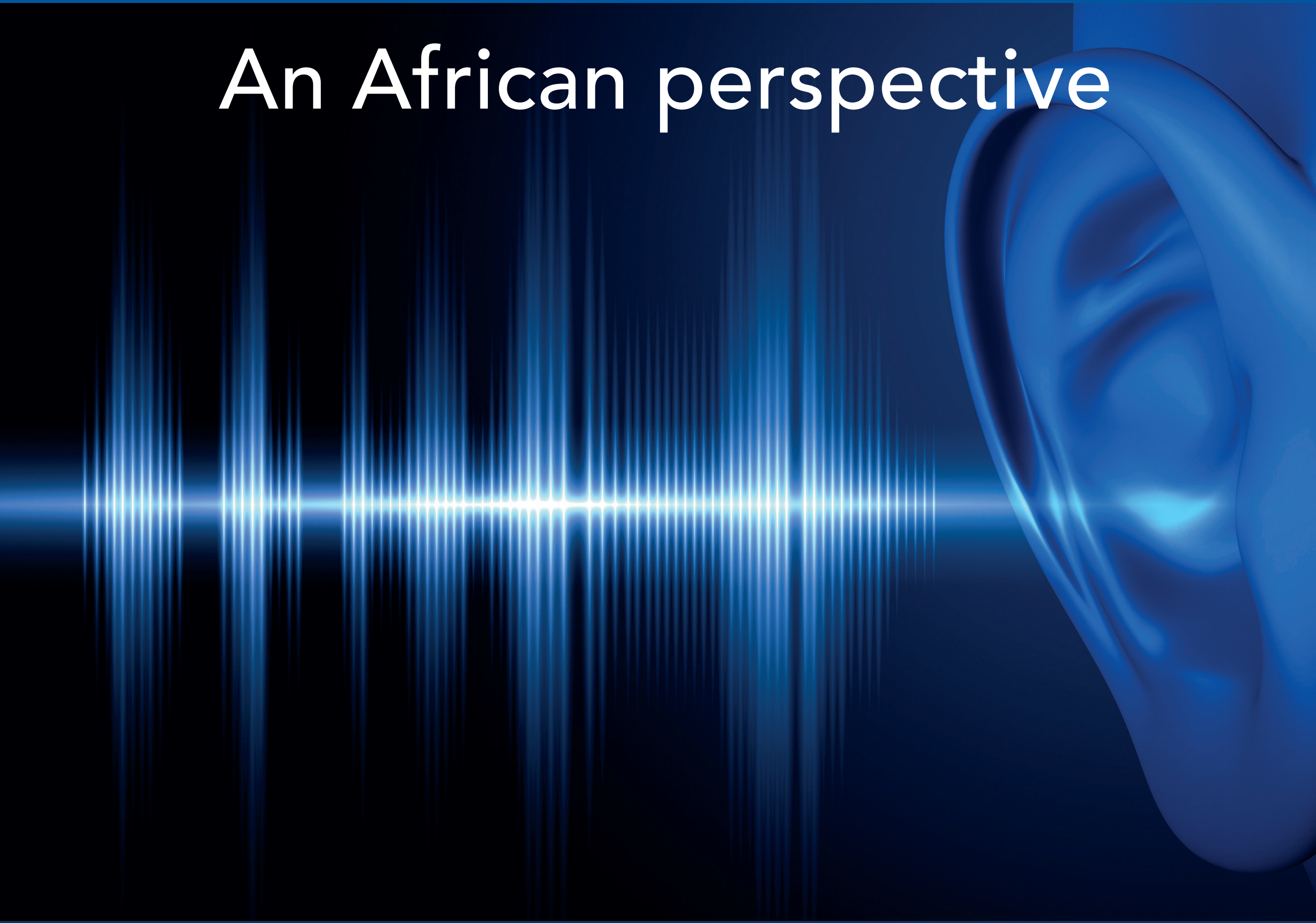
OCCUPATIONAL NOISE-INDUCED HEARING LOSS

An African perspective



Edited by Katijah Khoza-Shangase & Nomfundo F. Moroe

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Research justification

Within the well-documented understanding of occupational noise-induced hearing loss (ONIHL) being a complex occupational health condition requiring the adoption of the complex interventions approach to manage, challenges confronting hearing conservation programmes (HCPs) within the African context need clear characterisation and insightful deliberation. Guided by the systems theory, to be realistic about the implementation, monitoring and evaluation of outcomes of HCPs within the African mining context, similar to her other books, this book is Khoza-Shangase's call for a paradigm shift in the assessment and management of ONIHL and HCPs in African mines. *Occupational noise-induced hearing loss: An African perspective* equips occupational health care providers and researchers involved in the management of ONIHL and implementation of HCPs with evidence that allows for contextually relevant best practice in mines, particularly those located in low- and middle-income countries (LMICs). It also raises important implications for research, regulations and policy formulation within the African context. The best practice argued for is multidisciplinary in nature and engages all stakeholders in all relevant sectors, with the goal of adopting a *preventive* audiology approach to ONIHL rather than the *compensation-oriented* approach that is currently prevailing. This book is a research-driven contribution to the occupational health and safety (OHS) space, with ONIHL as a focus case study. It provides contemporary, contextually relevant and responsive evidence related to ONIHL and HCPs in LMICs, specifically focusing on the African context. The book expansively addresses all aspects of ONIHL and HCPs, with careful considerations of complexities and challenges to HCPs' implementation, applicable specifically to the African context but also useful to other LMICs and globally. The book offers potential solutions and recommendations for all challenges identified, having carefully and deliberately engaged with local evidence, local context and local policies and regulations, to ensure an Afrocentric contribution to the world of evidence.

The aforementioned is performed with strict observance of academic writing protocols such as critical engagement with evidence and adherence to plagiarism rules through consistent referencing. All chapters underwent a two-stage rigorous independent peer review by experts in the field and an independent review via AOSIS Books.

The chapters contain no plagiarism, and the book represents a scholarly discourse. The book's target audience consists of specialist researchers in the fields of audiology, engineering and occupational health.

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List of abbreviations and acronyms

1IR	First Industrial Revolution
2IR	Second Industrial Revolution
3IR	Third Industrial Revolution
4IR	Fourth Industrial Revolution
ABR	auditory brainstem response
ACOEM	American College of Occupational and Environmental Medicine
ADVI	Australian Driverless Vehicle Initiative
AEPs	auditory evoked potentials
AI	artificial intelligence
AIDS	acquired immune deficiency syndrome
ANR	active noise reduction
AR	augmented reality
ARHL	age-related hearing loss
ARNSHL	autosomal recessive nonsyndromic hearing loss
ART	antiretroviral treatment
ASSR	auditory steady state responses
AU	African Union
BBBEEC	Broad-Based Black Economic Empowerment Charter
BHP	Broken Hill Proprietary
BMI	body mass index
CARTA	Consortium for Advanced Research Training in Africa
CCOHS	Canadian Centre for Occupational Health and Safety
CHW	community health worker
cI	complex interventions
CO	carbon monoxide
cOIDA	*Compensation for Occupational Injuries and Diseases Act of 1993*
COVID-19	coronavirus disease 2019
CNN	convolutional neural networks
CSIR	Council for Scientific and Industrial Research
DALY	disability-adjusted-life-years

dB	decibel
DMRE	Department of Mineral Resources and Energy of South Africa
ECSA	Engineering Council of South Africa
EHDI	early hearing detection and intervention
FAES	field attenuation estimation system
FBA	feedback-based approach
FBNMM	feedback-based noise monitoring model
GDP	gross domestic product
GRS	genetic risk score
HCN	hydrogen cyanide
HCPs	hearing conservation programmes
HCSR	hazardous chemical substances regulations
HIC	high-income country
HIV	human immunodeficiency virus
HOG	histogram of oriented gradients
HPDs	hearing protection devices
HPCSA	Health Professions Council of South Africa
HTA	health technology assessment
HTL	hearing threshold levels
Hz	hertz
IAARC	International Association for Automation and Robotics in Construction
ICBEN	International Commission on Biological Effects of Noise
ICF	International Classification of Functioning, Disability and Health framework
ICTs	information and communication technologies
IHME	Institute for Health Metrics and Evaluation
IIoT	industrial internet of things
ILO	International Labour Organization
IoT	internet of things
IRs	industrial revolutions
ISSA	International Social Security Association
kHz	kilohertz
KPI	key performance indicator
LHD	load–haul–dump
LMICs	low- and middle-income countries
MBS	medicare benefits schedule
MCSA	Minerals Council of South Africa
MDGs	UN Millennium Development Goals of 2000

MHSA	*Mine Health and Safety Act of 1996*
MHSC	South African Mine Health and Safety Council
MPRDA	*Mineral and Petroleum Resources Development Act*
NCDs	noncommunicable diseases
NGS	next-generation sequencing
NHI	National Health Insurance Plan
NIDDM	noninsulin dependent diabetes mellitus
NIHL	noise-induced hearing loss
NIHLR	noise-induced hearing loss regulations
NIHSS	National Institute for the Humanities and Social Sciences
NIOSH	National Institute for Occupational Safety and Health
NRF	National Research Fund
NSHI	nonsyndromic hearing impairment
OAEs	otoacoustic emissions
ODMWA	*Occupational Diseases in Mines and Works Act*
OELs	occupational exposure limits
OHL	occupational hearing loss
OHP	occupational health care practitioners
OHS	occupational health and safety
OHSA	*Occupational Health and Safety Act of 1993*
OHSMF	occupational health and safety management frameworks
ONIHL	occupational noise-induced hearing loss
OSHA	US Occupational Safety and Health Administration
PAYE	pay-as-you-earn
PD	permanent disablement
PDMS	proactive data management system
PHP	personal hearing protection
PLH	percentage loss of hearing
PoPIA	*Protection of Personal Information Act of 2020*
PPE	personal protective equipment
QBoD	quadruple burden of disease
SAAA	South African Association of Audiologists
SASOHN	South African Society for Occupational Health Nursing
SASOM	South African Society of Occupational Medicine
SFMS	smart feedback monitoring system
SIMRAC	Safety in Mines Research Advisory Committee
SLH	speech-language and hearing
SNHL	sensorineural hearing loss

SNP	single-nucleotide polymorphisms
SRHS	standard for recording hearing sensitivity
SSW	Sibanye-Stillwater
STS	standard threshold shift
SUGM	Syama Underground Gold Mine
SVM	support-vector machine
TAC	treatment action campaign
TB	tuberculosis
Tele-HCP	telehearing conservation programme
UAV	unmanned aerial vehicle
UK	United Kingdom
UKHSE	United Kingdom Health and Safety Executive
UNAIDS	Joint United Nations Programme on HIV/AIDS
WAHTS	wireless automated hearing-test system
WHO	World Health Organization
YLD	years-lived-with-disability
YLL	years of life lost

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Section A

Occupational noise-induced hearing loss in Africa

Chapter 1

A call for a paradigm shift in hearing conservation programmes for the management of occupational noise-induced hearing loss in Africa

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1.1. Introduction

Moroe (2018) and Khoza-Shangase, Moroe and Edwards (2020), in their appreciation of occupational noise-induced hearing loss (ONIHL) as a complex occupational health challenge faced by African mines, declared that any form of intervention aimed at addressing this condition should adopt a systems theory approach in the form of complex interventions (CIs) to be realistic

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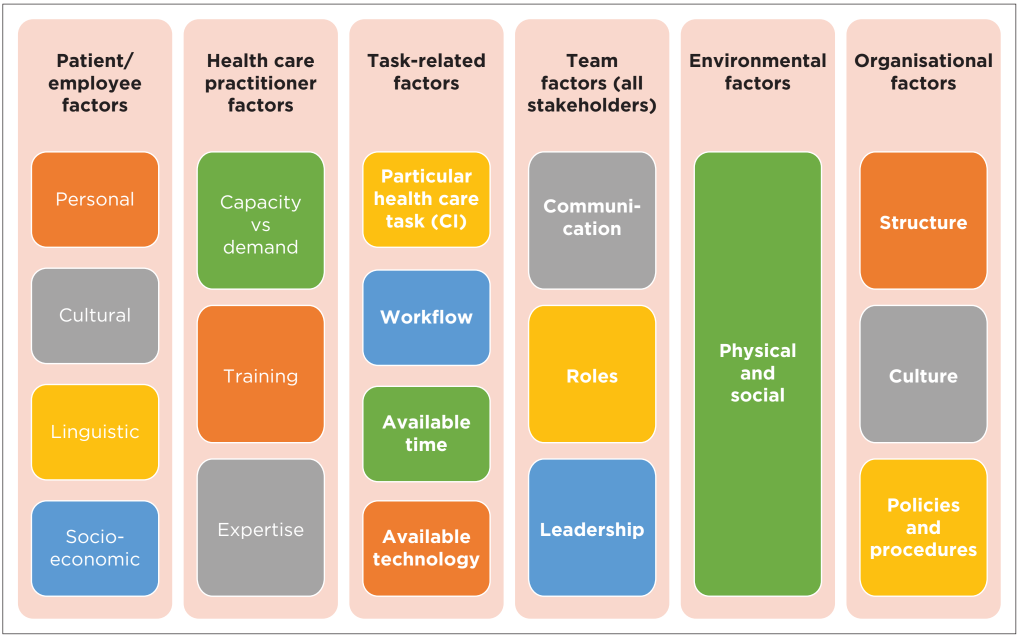
about its implementation, monitoring and evaluation of its outcomes. This proposed approach that hearing conservation programmes (HCPs) are well aligned with is guided by Kuipers et al.'s (2011, p. 11) conceptualisation of complexity and health care, where they underscore that health care complexity, as adopted in the context of this chapter on ONIHL, arises out of the interaction of multiple factors. These factors, as depicted in Figure 1.1, include the following:

1. patient or employee factors, such as personal, linguistic, cultural and socio-economic factors
2. health care practitioner factors (audiologists and occupational health practitioners), such as capacity versus demand factors, training and expertise
3. task-related (HCPs) factors, such as the particular health care task, available time, technology and workflow
4. team factors (all stakeholders), such as roles assigned, communication and leadership
5. environmental factors that include both physical and social aspects
6. organisational factors, such as organisational culture, structure, procedures and policies.

These authors averred that health care complexity is implicated in the rising health care costs, influences the perceived inequity in health care and, most



Source: Authors' own work.

FIGURE 1.1: Multiple factors that interact in complex interventions (hearing conservation programmes).

importantly, affects the quality and outcomes of care provided, as earlier submitted by De Jonge, Huyse and Stiefel (2006).

Current evidence from the African context, in countries such as Mali, Tanzania, South Africa, Ghana and Zimbabwe, indicates that this systems approach to ONIHL has not yet been adopted, with significant evidence pointing towards silo, fragmented and disjointed management of ONIHL within the mining industry (Amedofu 2002, 2007; Amedofu & Fuente 2008; Chadambuka, Mususa & Muteti 2013; Dekker et al. 2011; Edwards et al. 2011; Edwards & Kritzinger 2012; Edwards et al. 2015; Khoza-Shangase 2020a, 2020b; Moroe & Khoza-Shangase 2018a; Moroe 2020a, 2020b; Moroe et al. 2018, 2019; Musiba 2015; Mutara & Mutanana 2015; Ntlhakana, Kanji & Khoza-Shangase 2015; Ntlhakana, Khoza-Shangase & Nelson 2020a, Ntlhakana et al. 2021b; Pillay 2020; Pillay & Manning 2020; Strauss et al. 2014; Zungu et al. 2015). Therefore, the authors of this chapter call for a paradigm shift in the management of ONIHL and HCPs in Africa – with CIs being the approach adopted in planning, implementation, monitoring and evaluation of programmes within this context.

Complex interventions have been defined as those interventions that are developed from multiple interacting components, where components may act both independently and interdependently of each other (Moore et al. 2015). This is in congruence with Kuipers et al.'s (2011) conceptualisation, with the specification of the said components including behaviours, behaviour parameters and strategies of arranging those behaviours. Datta and Petticrew (2013) stated that outputs of these components and behaviours may have an influence at an individual, organisational and or population level, hence the current authors' belief of the appropriateness of this approach for the management of ONIHL. Because ONIHL is a multifaceted occupational health condition that does not occur in isolation from context and contextual influences or risk factors, recognition of this complexity is crucial for efficacious planning. These risk factors include pharmacological treatments for various burdens of diseases that are prevalent in this population (Brits et al. 2012; Khoza-Shangase 2010a, 2010b, 2011, 2017). Furthermore, because ONIHL is a condition that can only be prevented and managed (1) within this context through multistakeholder and multidisciplinary collaboration, (2) in HCPs that contain a variety of pillars that are arranged in a hierarchy of control and (3) within a systems approach, proper and comprehensive planning is necessary. The pillars of efficient HCPs include periodic noise exposure measurement and monitoring; audiometric evaluations; engineering and controls; employee and management education, training and motivation; the use of personal hearing protection; risk-based medical evaluation and medical surveillance; and efficient record-keeping (Amedofu 2007; Hong et al. 2013; Moroe & Khoza-Shangase 2022).

For HCPs to be successful within the African context, the authors of this chapter advance the argument that a CI approach allows for consideration of the following factors, as guided by the World Health Organization's (WHO) (2001) International Classification of Functioning, Disability and Health (ICF):

1. **Health care condition complexity:** ear care and hearing functions; ONIHL complexity, comorbidity and multimorbidity.
2. **Situational complexity:** environmental and mine factors, personal and employee factors, activities and participation.
3. **ONIHL and HCP complexity:** referral from the preventive level of care such as baseline audiometry testing, service fragmentation, funding for the HCPs, employee engagement, stakeholder thinking and HCP complexity, innovation and HCP complexity and perception of HCP complexity.
4. **Potential responses to ONIHL and HCP complexity:** evidence-based and contextually relevant and responsive HCPs comprising of all important pillars.

This book, therefore, is aimed at equipping occupational health care providers and practitioners in all spheres involved in ONIHL and HCPs with the capability to respond to this complex condition. Their response can be by (1) addressing issues around organisational learning through quality improvement and research; (2) highlighting the importance of collaboration-oriented responses to the management of ONIHL and HCPs with interprofessional and practitioner collaboration, including the use of paraprofessionals in task-shifting; (3) emphasising the importance of collaborative teams (communities of practice) and intersectoral collaboration; (4) proposing adoption of a preventive audiology approach to ONIHL where the goal is *elimination-oriented* rather than *compensation-oriented* to preserve employees' quality of life; and (5) empowering informed and active employees in HCPs, as well as advancing integrated and coordinated care of employees at risk for ONIHL and those already diagnosed with it.

The possibility of prediction and prevention of ONIHL has been well documented to be a reality globally if all pillars of HCPs are adhered to and if all factors contributing to its complexity are considered in the planning, implementation and monitoring of preventive initiatives (Khoza-Shangase 2022; Le et al. 2017; Metidieri et al. 2013; Moroe & Khoza-Shangase 2020; Moroe et al. 2018). Khoza-Shangase (2022) argued that a key barrier towards meeting this preventive target is monetarily driven, with employers being capital-driven rather than focused on the quality of life. Furthermore, within the South African mining context, this author asserted that the possibilities exist of deliberate efforts to obfuscate the development of the evidence base to lead best practice. In a systematic review by South African researchers where exposure to occupational noise in the African context was explored, Moroe et al. (2018) were the first to identify significant gaps in locally relevant evidence that could be used to inform practice aimed at achieving zero ear-and-hearing harm in this population. This review further revealed that the prevalence of ONIHL is still significantly high in these contexts, with enough evidence suggesting that the mining industry is fully conscious of this epidemic but seems to be experiencing limited success in eliminating it (Chadambuka et al. 2013; Dekker et al. 2011; Edwards & Kritzinger 2012; Edwards et al. 2015; Khoza-Shangase 2022; Musiba 2015; Mutara & Mutanana 2015; Ntlhakana et al. 2020a, Ntlhakana, Nelson & Khoza-Shangase 2020b).

Furthermore, Moroe et al.'s (2018) review findings revealed that studies within the African context focused mainly on four pillars of HCPs and did this in a piecemeal fashion that does not provide solid and coherent HCP management guidance. The four pillars that enjoy attention in the African mining research community include administrative and engineering controls; education and training; and personal hearing protection. Evidence suggests that record-keeping, periodic noise exposure monitoring and audiometric evaluations tend to be neglected. The noteworthy gaps in the Afrocentric evidence can be argued to contribute to the under-reporting of the real size of the ONIHL prevalence in the African context. Le et al. (2017) also argued that ONIHL is probably worse than currently assessed, so it is potentially a bigger problem than currently acknowledged globally.

Within the South African context, access to ONIHL and HCPs data for independent review and analysis has been documented to be a challenge. Moroe and Khoza-Shangase (2018a) added to the frequent criticism of the South African mining industry's prevailing poor OHS records, following a study aimed at exploring the feasibility of performing audiological investigations into ONIHL within the South African mining sector. In their study, these authors found that acquiring access to the South African mining sector for independent ethics committee-approved research is significantly challenging. These authors proffered the following reasons for this barrier to independent research: (1) contact details of individuals relevant to HCPs and OHS research are not readily listed on the mines' websites, (2) the response time following contact from independent researchers is significantly prolonged, if there is ever a response and (3) there is a reluctance to share data related to HCPs and management of ONIHL at various mines. Ntlhakana et al. (2021a) found that data capturing and management systems used in South African mines are not conducive to research, with concerns around poor integration of big data and uncertainties around regulations such as ethical regulations and the *Protection of Personal Information Act* (PoPIA).

Moroe and Khoza-Shangase (2018a) concluded that such access challenges are a major contributing factor towards barriers to the efficient implementation of evidence-based best practice in HCPs in this context. These authors posited that barriers to accessing data from the mines for research by independent and external researchers arguably influence the quality of the available evidence that is produced by the mines, as the use of internally generated evidence raises issues around a potential inevitable conflict of interest, where the mine serves as both referee and player in their own research. The success of HCPs relies on impartial evidence, irrespective of whether it portrays the mining industry in a favourable or unfavourable light. It is through open and honest critical engagement with such evidence that genuine and efficient solutions can be debated, reflected on and successfully applied. This evidence can also be useful if appropriate and efficient data capturing, management and storage systems are utilised.

Ntlhakana et al. (2020a) raised serious concerns about the limitations of the proactive data management systems (PDMSs) currently used in South African mines. Jantti and Cater-Steel (2017) presented that, as one focal point of contact for companies, a PDMS has been applied for several years to understand complex organisational trends. This is because PDMSs adhere to best practice principles, allow for efficient tracking of important factors identified by the organisation and furnish intervention methods and processes where needed, which Ntlhakana et al. (2020a) asserted are minimum requirements for an HCP. The use of the standard hearing threshold shift (STS) as a sensitive method for early detection of hearing loss was deemed a proactive practice of managing miners at risk for ONIHL by the South African Mine Health and Safety Council (MHSC) (2015), ensuring that audiological data in the mines are captured in this way is important. Ntlhakana et al. (2020a) found that this was not the case in their study, where data were still captured in a percentage loss of hearing (PLH). Furthermore, the PDMS used in these mines excludes data on other occupational exposures associated with ONIHL and miners' data on the burden of diseases such as TB and HIV as part of the miners' audiometry monitoring programmes.

All the aforementioned identified limitations to the PDMS prevent proactive management of miners at risk for ONIHL and serve as a barrier to early detection and intervention of ONIHL as part of preventive audiology goals. In a recent study, Ntlhakana et al. (2021a) argued that electronic data recording used by mines requires machine learning systems that can automatically classify and predict appropriate data and data that can allow for accurate and efficacious use in HCPs. In this study, the authors found that miners' audiometry and occupational hygiene, as well as medical surveillance data accessed from machine learning systems, may be inadequate, and ethical challenges may present themselves when trying to predict occupational hearing loss (OHL) as a measure of the mines' HCP effectiveness. These authors reported that, where data can be accessed, miners' audiometry and occupational hygiene data were available and accessible for research in the mine's HCP, but the medical surveillance records were not accessible for research purposes because of the ethical rule of confidentiality and the PoPIA serving as challenges to this data capturing (Ntlhakana et al. 2021a). This renders the mines' HCP data incomplete, which hinders the accurate prediction and prevention of OHL. The rights to access miners' medical surveillance data were unclear in these machine-learning systems. Ntlhakana et al. (2021a) concluded that although the ethical rules that govern miners' data and PoPIA were relevant, there appears to be incongruence between ethical rules and mine's laws that govern access to information for research. Furthermore, there appears to be a lack of clarity and consistency around data storage and access, which in turn hinders the efficiency of machine learning systems. Therefore, clarity around miners' data capturing, storage, management and sharing is required, with the employment of machine learning systems that have integrated codes for medical surveillance data, medical ethics and permission rights for research purposes.

Moroe et al. (2018) contended that to uphold accountability, effective record-keeping is vital and that this demands a high level of commitment and consistency from HCP administrators. Such commitment and consistency are crucial because of the gradual and progressive nature of ONIHL, requiring precise longitudinal data collection. These authors believe that such proper record-keeping allows for effective and accurate programme evaluation and alteration when necessary. Such use of data is also important for programme sustainability, if successful, and or programme changes where challenges are identified, similar to other preventive monitoring programmes such as ototoxicity monitoring (Khoza-Shangase & Masondo 2020).

Sound record-keeping also allows for the application of precise individualised conservation and monitoring programmes in employees who present with compounding risk factors such as concurrent exposure to other toxins (e.g. co-occurrence of tuberculosis – TB with ototoxicity) over and above noise exposure. Furthermore, in cases of compensation for OHS injuries, proper record-keeping allows for accurate comparative analysis of employee hearing thresholds where prevention measures have failed (Ntlhakana et al. 2020a). Consequently, proper records of leading indicators are required. Good records also facilitate empirical research that provides evidence-based recommendations that can enhance HCPs (Ntlhakana et al. 2021a).

The identified gap in research on HCPs in Africa implies limited application of best practice that is guided by relevant evidence. Moroe et al. (2019) responded to the gap in evidence and failure to achieve the desired outcomes of HCPs within the South African mining sector by proposing the application of a feedback-based noise-monitoring model (FBNMM) as a measure for managing and monitoring ONIHL. This FBNMM is a basic static model with practical applications in decision-making related to HCPs for all stakeholders in the mines, including the policymakers, mining managers and mineworkers. Moreover, this model is presented as possessing the potential to contribute to an early detection, intervention and management strategy for ONIHL in the workplace. The model is argued to be well-positioned to achieve these objectives because of its incorporation of policies around ONIHL and its comprehensive inclusion of all pillars of HCPs. Thus, it makes it sensitive and relevant to the context while being aligned to CIs. In a recent live application of the model, Moroe et al. (2020) utilised the FBNMM and illustrated how its application can facilitate the early prediction of ONIHL, thus providing earlier and more well-defined intervention as part of preventive audiology within the mine's OHS goals.

This FBNMM model highlights the significance of having qualified and registered health care practitioners, whose scope of practice is to manage ONIHL, be in the centre of HCPs and not be in the periphery, as is currently the situation in South African mines (Moroe & Khoza-Shangase 2018b). Prevention of hearing loss, a key goal of all advocacy campaigns to prevent ONIHL, falls within the scope of audiologists. This fact is especially important to remember in LMICs, where diverse priorities compete for attention within a resource-constrained environment. This reality is in the context of the identified contextual challenges influencing implementation of HCPs within the African context, with the well-documented capacity versus demand challenge represented by a significant incongruence between the numbers requiring audiological services and available audiologists being the topmost (Khoza-Shangase & Moroe 2020; Mulwafu et al. 2017; Pillay et al. 2020). Alternative service delivery models have been proposed, including the use of tele-audiology and task-shifting under the management of audiologists, to address this capacity versus demand challenge. Wade, Eliott and Hiller (2012, 2014) maintained that tele-audiology is beneficial in improving health outcomes, minimising adverse events, providing patients with options in service delivery models, and expanding access to ear-and-hearing health care services at home and in remote rural areas.

Khoza-Shangase and Moroe (2020) reviewed South African HCPs in the context of tele-audiology while exploring if tele-audiology can be applied in the assessment and management of ONIHL and HCPs. These authors take the value of contextual relevance to its logical conclusion by providing proposals around the utilisation of tele-audiology as a service delivery model because of its recognised relevance in resource-limited contexts, such as Africa. Because of the considerable capacity versus demand challenges in Africa (Mulwafu et al. 2017; Pillay et al. 2020) and the urgency for bolstering the implementation of HCPs by the audiology profession, Khoza-Shangase and Moroe (2020), supported by Khoza-Shangase (2022), recommended thorough reflection on tele-audiology as an adjunct service delivery platform in these settings. The advent of coronavirus disease 2019 (COVID-19), with its physical distancing requirements, makes this imperative an urgent need (Khoza-Shangase, Moroe & Neille 2021). The use of tele-audiology with task-shifting, where paraprofessionals meeting the Health Professions Council of South Africa's (HPCSA) minimum standards and regulations (in the case of South Africa), with overall programme management done by audiologists, will facilitate the planning, implementation and monitoring of successful HCPs within the African context.

In an edited special issue collection by Khoza-Shangase and Moroe titled *Occupational Hearing Loss in Africa: An Interdisciplinary View of the Current Status* (Khoza-Shangase et al. 2020), papers expansively covered matters of context, policy and law, assessment, management, evaluation and monitoring of OHL, as well as challenges and solutions for the African context. The papers in this collection address subthemes in the field of OHL that are either directly or indirectly related to the main theme, including (1) policy and legislation in the management of occupational noise, (2) contextual factors, barriers and or facilitators influencing implementation of HCPs, (3) other toxins contributing to OHL, (4) monitoring and evaluation factors in occupational noise and (5) recent advances in the management of occupational noise. Khoza-Shangase (2022) concluded that the current context provided by papers in this collection, as well as the recommendations for preventive audiology in ONIHL, emphasise the following central issues:

1. the importance of staying current with all recent developments and their application, bearing in mind contextual realities
2. the significance of situational and contextual analysis for the implementation of any programme
3. the significance of conversion of laws, regulations and knowledge into practice
4. the importance of collaborative implementation of HCPs, including all stakeholders with audiologists centrally located
5. the need to address OHL within a CI framework because of its complex nature.

As the first of its kind in Africa, this special issue allows for reflection of contextually relevant and responsive contemporary evidence that fills the gap in occupational audiology, while responding to the higher education call for knowledge generation to be Afrocentric to ensure that best practice is provided in the African continent – the motivation for the current book.

This book is divided into three sections. The first section focuses on ONIHL in Africa, with deliberations around motivation for a paradigm shift in how this complex occupational health condition is managed. It further confronts realities to HCPs in African mines, as well as exploring risk factors for ONIHL and contextualising these to the African context. The second section considers approaches to HCPs in the context of LMICs. Firstly, a focus is placed on HCP implementation in an African context, followed by an exploration of different classifications of audiograms in the prevention of ONIHL. This is followed by considerations of HCPs and industrial revolutions (IRs), as well as discussions on recent advances in engineering controls for HCPs for African mines. The last section carefully deliberates on the complexities of HCPs in Africa, with the exploration of HCPs in the context of OHS, HCPs in the context of burden of disease and HCPs in the context of tele-audiology, with the concluding chapter providing future considerations around best practice for HCPs in Africa.

In Chapter 4, the authors explore HCPs within the African context, paying specific attention to occupational audiometry to highlight factors surrounding screening versus diagnostic audiometry, including contextual practices and challenges relating to these. Factors such as the use of different measures and various classifications of audiograms during occupational audiometry are further explored in Chapter 5. This is where the authors deliberate on the use of the audiogram in HCPs, starting with its history and development. The use of the audiogram for compensation purposes, with a focus on the PLH and the STS as metrics for calculating hearing loss, is carefully deliberated on, with an African context case study from Tanzania on the use of the United Kingdom (UK) Health and Safety Executive (UKHSE) scheme for the categorisation of audiograms presented as an example. In Chapter 4, using South Africa as a case study, the authors offer solutions and recommendations for occupational audiology in action within HCPs in the South African context to facilitate the industry's ability to reach the targets set by the country's MHSC (2014a, 2014b). The targets are elimination of hearing deterioration in employees and minimisation of total noise emitted by any equipment. These recommendations come in the face of significant challenges that the South African mining industry must operate under and, consequently, challenges confronted by HCPs, arguably in most African countries.

Chapter 2 delves into these challenges comprehensively with the goal of extending the focus of the audiology and occupational health practitioners to influences that are ordinarily not considered during the conceptualisation, planning and implementation of HCPs. This chapter's author explores context-specific realities linked to the complex South African mining industry's governance by legislation and regulations (Nupen 2020). Similar to other African countries, occupational health stakeholders, such as audiologists, must contend with these realities in their attempts to address OHS hazards in the workplace. Influencing factors such as (1) lack of government enforcement of HCPs, with accountability uncertainty between labour and health ministries; (2) significant OHS challenges with a high burden of disease; (3) gender issues in mining; (4) market, investment and policy challenges; (5) general health care challenges; and (6) poor social determinants of health with which ONIHL must compete are all comprehensively covered in this chapter. Additionally, with the COVID-19 pandemic presenting additional challenges, deliberations on those challenges are also done.

Chapter 2 presents these realities plaguing South African mines with the goal to contextualise HCPs within the realities that exist in this industry and with the intention to prepare the audiologist for the implementation of contextually relevant and contextually responsive interventions in preventive audiology initiatives. Challenges faced by South African mines, which have been grouped into six categories, namely (1) the global economic collapse, and its effect on global demand; (2) uncertainty surrounding regulations and legislation; (3) infrastructure challenges: ports, energy, transportation and water; (4) workforce uncertainty; (5) burden of disease; and (6) licence to operate, environmental compliance obligations, illicit and unlicensed mining and local grassroots activism, are discussed with a nuanced presentation on how these influence HCPs' implementation within this context. Although this chapter uses South Africa as a case study, lessons presented can be contextualised to other African countries, and the solutions offered may be tested for the local evidence base there. Chapter 2 concludes by offering potential recommendations for HCPs that are cognisant of these challenges, recommendations that embed OHS as one of the core priorities in the South African context. The OHS priorities, specifically exposure to noise as an occupational hazard, are influenced by several risk factors that lead to outcomes that have several detrimental effects on health, including communication interference, cognitive effects, irritability, insomnia, fatigue and ONIHL (Basner et al. 2014; Chen, Su & Chen 2020; Masterson et al. 2016).

Chapter 3, guided by the recognised complexity of ONIHL and its highly preventable nature (Amjad-Sardrudi et al. 2012; Seixas et al. 2012), delves into the pathogenesis or the risk factors of ONIHL. The goal is to highlight the importance of comprehensive preventive measures that go beyond the noise in the mining industry. The author expansively explores the documented pathogenesis and risk factors of ONIHL, contextualising these within the African context. Following Golmohammadi and Darvishi's (2019) categorisation of risk factors, the author of this chapter presents the quadruple risks for ONIHL which are given as follows:

1. personal factors (age, gender, genetic background [genetic predisposition or heredity]), smoking, medication and drugs and contextual diseases – such as hypertension and cardiovascular diseases, diabetes, elevated triglycerides and cholesterol
2. chemical agents (solvents and carbon monoxide [CO]), heavy metals and other chemical substances such as organophosphorous pesticides; ototoxic chemicals (phosphorous compounds, cyanides and hydrogen cyanide [HCN]); and epoxy adhesive)
3. physical factors (lighting – illuminance, heat, vibration and cold)
4. occupational factors (workload and shift work).

Research reviewed in this chapter provides guidance to the African mining industry, audiology community and policymakers on where resources might best be utilised for preventive efforts in both future planning and reflection on the effectiveness of past interventions. Intervention strategies within HCPs should take careful cognisance of this evidence on pathogenesis to allow for the implementation of contextually relevant and responsive preventive programmes. Such awareness of influencing factors has been extended to external environmental factors in Chapters 6 and 7, where the IRs and advances in engineering controls in the context of HCP are presented.

Industrial revolutions, from the first to the last, have facilitated ground-breaking innovations and transitions from manual labour to powered machines, steam engines, mechanisation and, ultimately, easy access to the Internet, information technology and artificial intelligence (Dimitrieska, Stankovsk & Efremova 2018; Min et al. 2019). In the same vein, IRs have introduced and exposed workers to OHS hazards (Min et al. 2019), including ONIHL. Efforts to protect workers from hazardous noise exposure have also been influenced by the IRs. As such, the current Fourth Industrial Revolution (4IR) has been argued to have brought about cost-effective and easily accessible hearing conservation strategies (Brauch 2017). Chapters 6 and 7 carefully interrogate these developments and explore how they have and are influencing OHS. This includes their contribution to excessive noise in the workplace and opportunities for ONIHL prevention. In Chapter 7, the authors argue that the transition to fully automated mines brought about by IR will result in mineworkers, both in surface and underground mining, having minimum interaction with the mining environment, thus leading to less exposure to hazardous noise levels with a consequent reduction in prevalence and or severity of ONIHL within this context. These authors back this claim by presenting a novel feedback-based approach (FBA) that can be utilised in the transition period to automation. Using this FBA, the authors have observed that as the mining industry transitions to fully automated mining, fewer employees are exposed to hazardous occupational noise; therefore, most likely less ONIHL will be prevalent.

The deliberations and realities for HCPs within the African context occur under observed and documented complexities such as the presence and management of other OHS challenges, burden of disease and capacity versus demand quandaries. Because of poorly implemented OHS regulations, over 2 million occupational accidents are documented to occur every year, where approximately 6 000 workers die worldwide (International Labour Organization [ILO] 2014; Pillay 2020). Chapter 8 offers context for HCPs within these OHS accidents, highlighting the importance of regulations and adherence to these for employee wellness and safety, as well as for cost alleviation to the employer and the country's economy. With estimates indicating that nonfatal occupational accidents can cost approximately 4% of the world's gross domestic product (GDP) (International Social Security Association [ISSA] 2014), adherence to OHS regulations becomes of paramount importance. Chapter 9 argues for OHS programmes, and in the context of this book, HCPs, to consider the influence of the burden of disease for them to be effective.

Significant international and developing local research is available that affirms that ONIHL is influenced by several factors (Amiri et al. 2015; Amjad-Sardrudi et al. 2012; Bowens 2018a, 2018b; Chen et al. 2020; Concha-Barrientos, Campbell-Lendrum & Steenland 2004; Golmohammadi & Darvishi 2019; Khoza-Shangase 2020a), where their concomitant effect with noise exposure can yield antagonistic, synergistic, potentiation or additive influences for the employee exposed. The quadruple burden of disease, which South Africa has been documented to suffer from (WHO 2018), is one of these key factors that have an influence on ONIHL. Chapter 9 deliberates on HCPs in the context of the quadruple burden of disease in South African mines, with the exclusion of maternal and child mortality. Specifically, the relationship of communicable diseases, noncommunicable diseases, as well as injury and trauma to ONIHL is expansively covered, with the author highlighting the importance of including the burden of disease during benefit and risk evaluations of HCPs. This inclusion requires comprehensive and effective PDMSs, which African mines must procure as part of their goal to achieve positive preventive outcomes in this sector. Chapters 10 and 11 suggest that such effective HCPs can only occur if innovative service delivery models are employed within the African context, where capacity versus demand challenges are taken into consideration. These innovative methods include telepractice and the use of task-shifting, under adherence to regulations that will guide the professions while protecting the public.

As the use of telepractice steadily expands, with COVID-19 having accelerated the application of this model of health care service delivery recently, Chapter 10 argues that Africa has a unique opportunity to apply this model of health care delivery to increase access to occupational audiology, which currently is limited. Telepractice, in the form of tele-audiology, allows for the development and provision of ear-and-hearing health care services to people with no access to care (Audiology Australia 2020). Using innovative initiatives, such as the use of mobile apps, mobile clinics via teleconferencing and more (Wolfgang 2019), with negligible resources procurement and minimal additional training required to implement this model of service delivery in a number of existing practices, Chapter 10 declares that audiologists have an exciting opportunity to lead e-health practice – particularly with 4IR innovations expanding. This chapter, along with Chapter 11, explores this alternative method of audiology care delivery and utilisation of advances in technology and health care, with the goal of universal ear-and-hearing health care delivery in all African mines. A tele-HCP model is further proposed for audiologists working in occupational health settings, with considerations that need to be kept in mind in applying tele-audiology within the African mining industry presented. Chapter 10 concludes with the authors calling for serious consideration of this model of service delivery, with Chapter 11 carving a way forward with regard to offering best practice in HCPs for the African mining context.

1.2. Conclusion

Within the well-documented understanding of ONIHL being a complex occupational health condition requiring CIs approach to manage, challenges facing HCPs within the African context need clear characterisation and insightful deliberation. Guided by the systems theory to be realistic about the implementation, monitoring and evaluation of outcomes of HCPs within the African mining context, this book is a call for a paradigm shift in ONIHL and HCPs in Africa. The book equips occupational health care providers involved in ONIHL and HCPs with evidence that allows for contextually relevant best practice. This is a best practice that is multidisciplinary in nature and engages all stakeholders in all relevant sectors, with the goal of adopting a *preventive* audiology approach to ONIHL, rather than a *compensation-oriented* approach. In African countries where evidence does not exist, this book offers reflections on gaps that exist and potential directions to take in shared practice. This book is a research-driven contribution to the OHS space, with ONIHL as a case study, and provides current, contextually relevant and responsive evidence related to ONIHL and HCPs in Africa, with South Africa often used as a case study as the preponderance of evidence currently emanates from there. The book expansively addresses all aspects of ONIHL and HCPs in one volume with careful consideration of complexities and challenges to HCP implementation, applicable specifically to Africa and LMICs, although useful globally. The book offers potential solutions and recommendations for all challenges identified, having carefully and deliberately engaged with local evidence, local context and local policies to ensure an Afrocentric contribution to the world of evidence.

Chapter 2

Confronting realities of hearing conservation programmes in South African mines

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2.1. Introduction

Implementation of HCPs continues to be a significant challenge within South African mines. This is despite their well-documented benefits towards minimising and or eliminating ONIHL. There exist context-specific realities, similar to other LMICs, that occupational health stakeholders must contend with in their attempts to address occupational health hazards, such as ONIHL. The South African occupational audiology community must function within such contextual realities in an environment that includes the seeming lack of government enforcement of HCPs, over and above (1) accountability uncertainty between labour and health ministries; (2) significant health and safety challenges with a high burden of disease; (3) gender issues in mining;

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(4) market, investment and policy challenges; (5) general health care challenges; and (6) poor social determinants of health. Occupational noise-induced hearing loss must compete with all these factors while also being significantly influenced by them. With the advent of the coronavirus disease 2019 (COVID-19) pandemic, additional challenges and the heightening of existing challenges have also been documented.

Nupen (2020) stated that even though the South African mining industry is significantly governed and controlled by laws and regulations, it remains complex with numerous challenges that it must deal with. The current challenges most pressing to the employer, among others, include (1) the publication of recommended guidelines for the relocation of groups of communities residing around mines, (2) the suggested changes to the retrenchment aspect of the regulations published relating to the *Mineral and Petroleum Resources Development Act*, 2002 (MPRDA) and (3) the currently accepted as valuable 'once empowered, always empowered' clause which is embedded in the recently published 2018 Mining Charter (Nupen 2020).

This chapter deliberates on the various issues plaguing South African mines, with the goal to contextualise HCPs within the realities that exist in this industry. The intention is to prepare the audiologist and other relevant stakeholders for the implementation of contextually relevant and contextually responsive interventions in preventive audiology initiatives within this scope of practice. The chapter begins by defining HCPs and their current status within the South African context. This is followed by a presentation of South African mining in context to introduce the reader to this sector. This is then followed by a more detailed and focused discussion on the challenges faced by South African mines. These challenges have been grouped into six categories, and they include (1) the global economic collapse and its effect on global demand, (2) uncertainty surrounding regulations and legislation, (3) infrastructure challenges: ports, energy, transportation and water, (4) workforce uncertainty, (5) burden of disease and (6) licence to operate, environmental compliance obligations, illicit and unlicensed mining and local grassroots activism. Lastly, the chapter offers possible conclusions and recommendations for HCPs that are cognisant of these challenges. Furthermore, these recommendations consider the mining industry plans aimed at addressing these challenges which embed health and safety as one of the core priorities in the South African context.

The HCPs are multi-component and CIs that have management of exposure to extremely unsafe occupational noise at work to prevent ONIHL as their main goal. This is a condition that is known to be preventable (Amedofu 2007; Hong et al. 2013; Khoza-Shangase & Moroe 2020a; Moroe 2020; Seixas et al. 2011). For HCPs to be successful, the literature suggests that effective implementation coverage and adherence to all HCP pillars according to the stated hierarchy of control is critical (Khoza-Shangase & Moroe 2020b). These pillars include (Amedofu 2007; Hong et al. 2013):

1. administrative controls
2. education, motivation and training of employees and workplace management
3. engineering controls
4. use of personal protective equipment (PPE) such as personal hearing protection
5. serial noise exposure measurement and monitoring
6. risk-based medical assessment, medical observation and audiometric evaluations
7. record capturing and storage.

Sufficient evidence exists that illustrates the efficacy of HCPs in preventing ONIHL, albeit this comes mostly from high-income countries (HICs) (Davies, Marion & Teschke 2008; Dobie 2008; Lie et al. 2015; Nelson et al. 2005; Rabinowitz 2012). In their systematic review, Moroe and Khoza-Shangase (2020) found that significant recent advances have been achieved internationally in HCPs. Low- and middle-income countries (LMICs) can learn from and implement these recent advances in their contexts for successful ONIHL prevention outcomes. These contemporary developments have been displayed under seven themes, given as follows: (1) utilisation of metrics, (2) developments around noise monitoring, (3) conceptual approaches to HCPs, (4) audiology evaluation procedures, (5) interventions around the use of pharmacological agents and hair cell regeneration, (6) artificial neural network and (7) eliminating noise from the source – buying quiet (Moroe & Khoza-Shangase 2020). These authors recommended that the practicability and effectiveness of these new developments require careful deliberation and establishment to guarantee local contextual relevance and responsiveness.

Currently, local evidence indicates that HCPs are not yet successful within the South African context (Khoza-Shangase, Moroe & Edwards 2020). Chapter 4 deliberates on the reasons why this is so. In a special issue journal titled ‘Occupational hearing loss in Africa: An interdisciplinary view of the current status’, Khoza-Shangase et al. (2020) as guest editors of the special issue, directed by findings from several investigations (Dekker et al. 2011; Edwards & Kritzinger 2012; Edwards et al. 2015; Grobler et al. 2020; Mapuranga et al. 2020; Moroe et al. 2020; Ntlhakana, Nelson & Khoza-Shangase 2020; Pillay 2020; Pillay & Manning 2020) to assess the practicability and efficacy of OHL management within the African mining industry, highlighted these adverse outcomes of HCPs. This special issue systematically covers issues of context, evaluation, monitoring, intervention, policy and law, with challenges and recommendations on how to address them regarding HCPs and OHL within the African context. From the issue, these editors highlighted the following key issues for positive outcomes to be achieved within the African context (Khoza-Shangase et al. 2020):

1. the complex nature of OHL and the significance of handling it by adopting a complex intervention framework
2. the necessity to stay as courant with contemporary developments and their contextually relevant implementation
3. the significance of context analysis in programme implementation
4. the importance of collaborative engagement of all relevant stakeholders for successful implementation of HCPs within CIs, with audiologists centrally located
5. the value of conversion of knowledge, laws and regulations into clinical practice.

2.2. South African mining in context

The success of HCPs within the South African context compels knowledge and appreciation of the numerous challenges facing the mining industry within this context and the strategies aimed at addressing these challenges. Understanding this context will ensure that planning, implementation and monitoring of HCPs are done in a manner that is programmatic and aligned to priority indicators for the industry. Beech (2014) argued that the numerous difficulties confronting the South African exploration and mining industry can be encapsulated into eight fundamental challenges:

1. the global economic collapse and its effect on global demand
2. grassroots activism
3. illegal mining
4. workforce uncertainty
5. health and safety
6. environmental compliance requirements
7. infrastructure challenges such as ports, energy, transportation and water
8. uncertainty surrounding regulations and legislation.

Some of these difficulties, later expanded on in this chapter, have lately been echoed by Mbazima (2020), who further offered some solutions to these challenges for the South African mining context. This author asserted that South African mining, which he argued is in decline (like several other South African industries), needs to act to transform and revolutionise the industry for growth and competitiveness to be able to resolve these enormous challenges. Following an analysis of the bases of the South African mining industry decline, under structural reform for competitiveness, Mbazima (2020) proffered numerous fundamental proposals to resuscitate the industry, with the improvement of investments' competitiveness being a key focus. This author holds the position that investment-competitiveness is the indispensable facilitator for the development of the South African mining industry, and consequently, more focus should be placed on global competitiveness to attract the capital required to recover and grow the industry.

Based on a comparison of the South African mining industry in the periods 2010 and 2018, Mbazima (2020) concluded that:

> These are extraordinary times and there is little time to mince words: South African mining is in decline. We have limited exploration for new mining opportunities. We have almost no investment in new mines. We have decreasing investment to expand and maintain existing mines. The capital flows into South African mining are drying up. In short, South Africa is mining out a declining pool of reserves with existing mine infrastructure. And if you mine out existing reserves without investing in finding new reserves and building new mines, output will inevitably shrink, as is already happening in South Africa. (p. 1)

These strong conclusions are based on the outcomes of the aforementioned comparison which revealed the following three key observations: (1) real output value when expressed in dollars has decreased by 10%, (2) total direct employment has contracted by 50 000 and (3) annual capital expenditure has almost bisected (reduced by 45%). Although Mbazima (2020) highlighted the nuanced differences between subsectors in this industry, for example, where certain traditionally bigger sectors have shown substantial declines, some have presented modest growth. This author shone a light on the aggregate picture of a clear structural decline of the South African mining industry. This reality has implications for all initiatives within the industry, including health and safety programmes such as HCPs.

The Chamber of Mines of South Africa (2016) provided a list of challenges facing South African mines, and they are:

1. unsuitable use of regulatory instruments
2. deteriorating productivity and rapidly ever-increasing costs
3. social wage pressures leading to labour market instability and disproportionate wage demands
4. viability difficulties confronting coal, gold and platinum sectors
5. obligatory infrastructure restrictions (shortages in electricity supply since 2007)
6. mineral prices in Rand terms have idled or weakened
7. regulatory and policy uncertainties, notwithstanding attempts to resolve these.

All these challenges raise serious implications for an industry that is stated to serve a critical function in the evolution and growth of any country globally

(Agwa-Ejon & Pradhan 2018). Khoza-Shangase and Moroe (2020a) highlighted how, in South Africa, mining and all industries related to it are indispensable for socio-economic growth. The Chamber of Mines of South Africa (2013) asserted that South African mining does not only contribute significantly to the country's economy but also to that of the African continent. In 2019, the Minerals Council of South Africa reported that the mining sector contributed R351bn to the South African GDP in the year 2018, with statistics for 2016 revealing a contribution of approximately 7.9% towards the total GDP (Stats SA 2017). This contribution has subsequently decreased by 15% (Van Zyl 2019), and this serves as good evidence for Mbazima's (2020) claims. Mbazima (2020) argued that lacking meaningful intervention to change this course, it is projected that employment, output and GDP and fiscal contributions will persist in deteriorating.

Kistnasamy et al. (2018) lamented how South Africa's mineral resources produce substantial economic prosperity, regardless of the excessive levels of occupational lung disease, OHL and difficulties with low rates of compensation for retired mineworkers, facilitated by years of apartheid, colonialism, capital flight and post-apartheid challenges. Hence, the African Union (AU) provides its Africa Mining Vision. This vision views mining as a way towards economic growth and industrial development. However, this Union is very clear about the value of evaluating benefit versus risk and strongly asserts that mining should not occur at the expense of a 'safe' and 'healthy' 'sustainable and well-governed' sector (AU 2016). This position is an important consideration when solutions surrounding the listed challenges facing the South African mining industry are being proffered.

Knowledge and understanding of the challenges faced by South African mines, as presented by Beech (2014) and Mbazima (2020), are what made Coulson (2018) relevant in planning, implementing and monitoring HCPs. Coulson (2018) asserted that the rush for economic inflation on the African continent in the past 10 years, where substantial job creating and poverty alleviation burden are evident, can deflect focus away from the AU's aim of a safe and healthy workplace. This author believed that OHS in hazardous workplaces has a deficient foundation in Africa (Coulson 2018). Alli (2008), on the contrary, claimed that on various occasions, OHS legislation is inadequate or obsolete, that there is an enforcement deficiency by labour inspectorates and that there is a paucity of reported information on occupational diseases and injuries. It is therefore important for OHS programmes, such as HCPs, to be cognisant of the challenges confronting South African mines, as depicted in Figure 2.1. This will ensure that they position themselves centrally to the growth and sustainability of the industry, rather than peripherally.

Source: Author's own work.

FIGURE 2.1: Challenges confronting South African mines.

2.3. Challenges confronting South African mines deliberated

2.3.1. The global economic collapse and its effect on global demand

Ravinder and Malindi (2014) described how the global financial crisis, characterised by the four main financial crises, has, since the first financial crisis era, been caused by exceptional variabilities in the goods prices, shares and housing, as well as foreign exchange. The four main financial crises are:

- the early 1980s Latin American financial crisis
- the early 1990s Japanese financial crisis
- the mid-1997 East Asian financial crisis
- the 2007–2008 global financial crisis and the successive Euro debt crisis.

Like the global outlook, this financial collapse has had a considerable impact on South Africa (Powell & Steytler 2010). For the first time in 19 years, the economy is reported to have plunged into recession in 2008–2009, leading to approximately one million jobs being lost in the year 2009 alone (Powell & Steytler 2010; Ravinder & Malindi 2014). This unemployment rate has continued to remain high and is rising, with it being initially at 28.5%, up from 26.9% in 2018 (Plecher 2020), and is currently at a new record high of 32.6% in the first quarter of 2021 (Reuters 2021). There is evidence of economic growth steadily recommencing marginally recently, albeit with fragility (Ravinder & Malindi 2014), and this fragility was keenly exposed by the current crisis presented by the COVID-19 pandemic.

The South African Supplementary Budget Review (2020) highlighted that the COVID-19 pandemic and the emergency health response that has had to be established both nationally and globally have ushered in a severe global recession. The restrictions on economic activity as part of the virus spread containment measures were expected to lead to a 7.2% fall in South Africa's real GDP growth in 2020 (Supplementary Budget Review 2020). This has serious implications for poverty and escalating unemployment, which have placed more intensified demands on state resources in the context of contracting revenues. Consequently, the South African Treasury accepts as true that consolidation of South Africa's competitiveness post-COVID-19 will necessitate a novel social compact, resolute application of transformative reforms to enhance the structure of the economy and clear-sighted action to steady debt and contract the budget deficit (Supplementary Budget Review 2020), regardless of political coercion on the State to appraise its economic policy (Ravinder & Malindi 2014).

As far as cost competitiveness is concerned, Mbazima (2020) conducted a comparison of costs per unit of production for South African mines. In this comparison, findings revealed that over 60% of South Africa's mining output (as measured by value) does not emanate from mines that are in the top half of cost competitiveness but from those in the bottom half. He described this as indicating that South African mines characteristically possess greater production costs per unit of output. The implications of this reality are that South African output will become highly at risk if commodities demand is lowered. Essentially, if prices and demand fall because of these comparably excessive unit production costs, South African mines will develop into some of the first to fail in being profitable. Recommendations to resolve this crisis have included an establishment of an exploration strategy that includes attracting exploration investment, regulatory amendments to improve exploration attractiveness (e.g. trading of minerals licences without gratuitous government intervention and with more efficient, objective and fast applications processes), geological and geosciences solutions that are comparable to global best practice and so on (Mbazima 2020). Further recommendations aimed at mitigating the global financial crisis impact on global demand within the South African mines, over and above investment promotion, include investment in industry modernisation, where prospects to advance cost efficiency through correct investments exist (Cornish 2020; Mbazima 2020). Mbazima (2020) believed that for the South African mining industry to be able to boost its competitiveness and investment, one key goal should be to address executional certainty by establishing a special task force, where implementation, coordination and systematic monitoring of plans and initiatives occur.

2.3.2. Uncertainty surrounding regulations and legislation

Lane, Guzek and Van Antwerpen (2015, p. 471) argued that the South African mining industry is in a challenging situation because ‘operating conditions are tough, the socio-political environment is complex, and financial performance is under pressure’. Lane et al. (2015) presented global influences to include sluggish global economic recovery, a tendency towards resource nationalism, moribund or failing commodity prices, urbanisation and industrialisation and the potential of Africa. Local influences are said to include regulatory environment uncertainties, under-pressure margins, labour instability and increasing demands by the government (Lane et al. 2015). It is for these reasons that Mbazima (2020) asserted that confronting and addressing the current regulatory and legislative uncertainly are key to the survival, prosperity and sustainability of the South African mining industry.

Moalusi and Malesa (2019) argued that the uncertainty surrounding policy and regulations that has beleaguered the South African mining industry for some time significantly improved in 2018. These authors believed that this uncertainty was mainly because of (1) the deferral in concluding the MPRDA – Amendment Bill that has been under legislative processes since 2013 and (2) the Department of Mineral Resources’ publication of the Reviewed Broad-Based Black Economic Empowerment Charter (BBBEEC) for the South African Mining and Minerals Industry in 2017 (‘the 2017 Mining Charter’), following strong objections by the mining industry as evidenced by the multiple court challenges. The reported improvement achieved in 2018, as stated by Moalusi and Malesa (2019), was because of (1) the withdrawal of the Amendment Bill and (2) the publication of the new 2018 BBBEEC (‘the new Mining Charter’).

The mining industry applauded the withdrawal of the Amendment Bill, and it signalled a progressive stride towards regulatory and policy certainty. This change signified that mining companies could, going forward, function under current MPRDA-stated provisions (Mbazima 2020; Moalusi & Malesa 2019).

Mbazima (2020) cautioned that the current iteration of the Mining Charter, which regulates mining in South Africa, continues to fuel regulatory framework uncertainty. This author argued that the conversation about mining regulatory uncertainty will remain long after uncertainties linked to the iteration of the Mining Charter have been resolved, and he attributed this directly to the existence of a charter. Consequently, Mbazima (2020) recommended the abandonment of a charter, but without cancelling the redistributive requirements encompassed in the Mining Charter. The redistributive requirements should rather be agreed upon and written explicitly into law for investors to access and apply. The move away from a charter presents challenges because it can change, with the timing of the change being any time, therefore meaning that the mining industry (10–30-year investment) is regulated by a malleable regulatory instrument. Mbazima (2020) suggested the adoption of the global best practice, which suggests regulation by straightforward, distinct, direct legislation that has in-built stability – not a charter. He argued that regulation by legislation will bring stability, competitiveness and certainty because of the very long-term nature of legislation and the requirements of a thorough legislative process for an Act to modify. This author believed that amendment of the MPRDA to align with global best practice will essentially eradicate the necessity for a charter, but he stressed the importance of ensuring that the regulatory requirements agreed upon by all stakeholders are secure and lasting, are competitive and promote South Africa's transformation and socio-economic agenda.

The author of this chapter is of the view that OHS initiatives, such as HCPs, must contend with all these regulatory uncertainties as investments directed towards mining have implications for any measures put in place for either preventive initiatives and/or management of ONIHL by the sector.

2.3.3. Infrastructure challenges: Ports, energy, transportation and water

Over and above the challenges around attracting investment into the South African mining industry, challenges around infrastructure significantly contribute towards the decline and or limited growth where opportunities exist (Chamber of Mines of South Africa 2016; Mbazima 2020). Accessible, efficient and cost-effective infrastructures such as ports, rails, water, roads and electricity are key to successful mining (Chamber of Mines of South Africa 2016). Mbazima (2020) believed that infrastructure challenges restrict the overall production capacity to less than the full potential of available assets and prevent the exploration of potential new assets. He therefore suggested that availability and efficiency of, as well as competitive rates for, the utilisation of this infrastructure is possibly one of the biggest controls to release recognised potential output growth in South African mining. The fact that, in 2019, load-shedding and above-inflation electricity price increases are documented to have resulted in the loss of between R7bn and R12bn in output for the South African mining industry, which equals 4% of the total industry output, has serious revenue implications for this industry – over and above the operational challenges introduced by load-shedding (Mbazima 2020). The uncertainty in the ability to operate effectively, as well as its implications on profitability, negatively influences the potential investment in the South African mining sector, in the context of a globally competitive investment environment (Cawood 2011).

2.3.4. Workforce uncertainty

Cawood (2011) offered an impartial observation of the investment climate for South African mining, where he highlighted that the lack of balance between labour legislation and labour efficiency poses a threat to the South African mining industry. South African mines require skilled labour and access to staff who can potentially be trained to become skilled and productive. This requirement is reported to be challenging to meet as the quality of education in South Africa is ranked poorly when compared with the majority of other countries, although fourth in Africa (Chime 2019). The standard of mathematics and science is reported to be even worse. This level of education does not support a world-class mining industry that is globally competitive in a sustainable manner.

The legacy of apartheid remains, which is that historically the workforce in the mining industry comprised a majority of black male employees, who were previously disadvantaged in terms of education and skilled labour (Kane-Berman 2017; Smit & Mji 2012). Apartheid and its legacy have left a devastating outcome not only for the mineworkers but also for their families, the mining industry and the State at large. The low levels of education and literacy because of past social and economic injustices imposed on black people during the apartheid era have left most mineworkers illiterate, thus confining them to manual labour jobs that do not demand any type of education (Smit & Mji 2012). Arguably, there may have been improvement in recent years because of the surge of millennials in the mining industry. Low levels of education, high unemployment rate, lack of skill diversity, etc., all place the mining employee in a vulnerable position within a profit-driven pressurised environment. This environment prevents health and safety considerations from being properly advocated for and insisted on, hence the importance of understanding the context within which HCPs are being implemented.

The negative effects of low levels of education and unskilled labour of the majority black workforce have translated into a race wage gap in the mining sector. Kane-Berman (2017) reported that in the 1970s, the average salary for a white worker was 16 times more than that of a black worker. These salary differences were based on different skill levels, the results of the industrial colour bar and the Bantu education system that ensured that black people remained unskilled (Kane-Berman 2017). Because labour unions were banned during the apartheid regime, these conditions could not be negotiated. In a gold mine in 2003, post-apartheid, it is documented that the average entry-level salary for a mineworker was approximately R5 000, increasing to approximately R8 000 inclusive of housing and food allowance. With bonuses, these salaries were reported to rise to approximately R11 000 a month overtime (Reuters 2013). Because of this inconsistency regarding living conditions and salaries of mineworkers in South Africa, mineworkers embarked on a massive industrial action in 2012 which resulted in what is now dubbed the Marikana Massacre. This is where 34 people were killed and 78 wounded (Hill & Maroun 2015).

To understand the Marikana Massacre, a historic understanding of the South African mines' employees living conditions is important. Before 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 absconding from work, discourage drunkenness and minimise the risks of theft (Kane-Berman 2017). The living conditions in the compounds were unhygienic and unhealthy (Wilson & South African Council of Churches 1972); consequently, diseases such as tuberculosis (TB), HIV, AIDS and silicosis became rife in the mining sector (Churchyard et al. 2000; Sonnenberg et al. 2005; Stuckler et al. 2011, 2013). The presence of HIV increases the possibility of acquiring TB, which is aggravated by poor living conditions (Bhunu, Mushayabasa & Smith 2012; Stuckler et al. 2013). According to the World Bank, as cited by Cullinan (2018):

> In South Africa alone, TB rates within the mining workforce are estimated at 2500–3000 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. (p. 1)

These assertions were made with regard to the R1.4bn settlement for miners who contracted silicosis and TB from 12 March 1965 to date. One of the claimants from this class action stated (Cullinan 2018):

> 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. (n.p.)

Regarding the compensation awarded to the miners, some supporters expressed their views (Cullinan 2018):

> 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. (n.p.)

The analysis of the Marikana Massacre revealed several issues that significantly contribute towards labour uncertainty in the South African mining industry – over and above education and skilled labour. Moroe (2018) presented five of these issues:

1. There was criticism against the government of the African National Congress ruling party, as well as the state system, for what was deemed their failure in tackling mineworkers' problems (Twala n.d.).
2. The regulatory and legislative uncertainty within the mining industry also had an impact on the workers. The government had been ineffective in implementing the Mining Charter, which, among other things, compelled mining companies to provide housing for all mineworkers.
3. The labour unions had been ineffective in handling the workers' grievances adequately.
4. Mineworkers were angry about what they viewed as the greed of the employers and the mining industry (Twala n.d.). Although it is recorded that after 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), mineworkers continued to earn minimally and were living under poor conditions.
5. The mining industry had fragmented its labour force of 180,000, allowing approximately 82 000 workers outsourced through labour brokering. Additionally, employees were segregated on regional, ethnic and racial grounds, which led to increased aggravations among workers who witnessed employers persisting getting richer at their expense while they 'sweat underground, face death on a daily basis and sink deeper into poverty' (Twala n.d., p. 62).

Females in mining experience additional challenges to the ones presented. Under labour uncertainty, one can argue that the issue of workplace challenges, regardless of progressive gender-responsive regulations that females in the South African mining sector still confront, requires significant consideration. These challenges specifically include prejudice in decision-making and in salaries, as well as limited career progression (Kaggwa 2020), over and above gender-specific health and safety challenges (Zungu 2012). Kaggwa (2020) had put forward evidence-informed suggestions on strategies to stimulate sustainable gender parity in South Africa's mining sector. Key to the recommendations this author made is the need to realise that legislation alone is not sufficient as an intervention tool in alleviating workplace challenges faced by female employees and in easing gender disparity in the mining sector. Kaggwa (2020) suggested that concerted steps aimed at skills development for females to facilitate an upward trajectory in the employment level hierarchy must be deliberately taken, while breaking new ground for senior responsibilities for these females to occupy in the industry.

In a male-dominated sector, with regard to anatomical and physiologic differences between females and males, the unique health and safety needs of females need consideration. Zungu (2012) highlighted that the underground environmental conditions such as unhygienic sanitary amenities and PPE are some of the challenges that females in mining confront. This author recommended that, to improve female health problems related to these challenges, focus must be placed on the improvement of PPE and underground sanitary amenities.

Recently, Thasi and Van der Walt (2020) raised the alarm regarding the dearth of core occupational skills categories reaching catastrophic levels in the South African mining industry. These authors argued that this extreme shortage is because the demand for skilled and qualified employees surpasses the available supply. This incongruence leads to the overburdening of the available employees with duties and responsibilities. Furthermore, this increases stress (Masia & Pienaar 2011), leading to the current exodus of qualified employees. Khalane (2011) and Oberholzer (2010) reported that engineers and artisans are the main occupational categories where South African mines experience critical skills shortages. Khoza-Shangase et al. (2020) argued that this demand versus supply challenge cuts across all professional categories in mines, including those responsible for OHS, such as audiologists.

Evidence of published data on the management of ONIHL in South African mines indicates that there is minimal involvement of audiologists in this area (Moroe & Khoza-Shangase 2018). While there are several studies conducted by audiologists in the management of ONIHL in the mining sector, there is a paucity of studies with a focus on the role and involvement of audiologists in the planning, implementation and monitoring and evaluation of HCPs in South African mines. This is despite HCPs being defined as falling within the scope of practice of audiologists, both internationally (American Academy of Audiology 2003), and locally (HPCSA 2012). Audiologists are responsible for ‘designing, implementing and coordinating occupational and community hearing loss prevention programmes’ (American Academy of Audiology 2003). Although the role of audiologists in occupational health is clearly defined in scopes of professions and in regulations, evidence indicates that both internationally and locally, there are limited audiologists who operate as consultants in the mining industry. There are even fewer audiologists engaged in HCPs tasks such as training of occupational hearing conservationists, measurements of noise levels or in HCP implementation and reviews (American Speech-Language-Hearing Association 2004; American Academy of

Audiology 2003; Khoza-Shangase & Moroe 2020a; Moroe & Khoza-Shangase 2018). The absence of audiologists in the management of ONIHL within the South African mining context has serious consequences for the mining industry, as audiologists are professionals knowledgeable in noise and its short- and long-term effects on employees with excessive occupational noise exposure (Khoza-Shangase & Moroe 2020b).

A global net shortage of health care workers approximating 15 million health care workers by 2030 has been predicted globally, with LMICs unable to meet their own demand (Wilford et al. 2018). This does not only have implications for general health care, but it also has implications for the health and safety of mineworkers, to which capacity versus demand challenges extend. Khoza-Shangase (2021) recommended increased efforts by audiologists towards the use of task-shifting and upskilling of non-professionals under proper regulations that protect the public. Wilford and colleagues (2018) advised that to boost efficiency, all health systems will need to explore task-shifting and upskilling, as well as make the best use of community health workers (CHWs). In the case of HCPs, the author of this chapter suggests training primary health care nurses, where decentralisation and professionalisation of certain aspects of HCPs, such as education and awareness, noise measurements and monitoring, screening, et cetera, as part of preventive health care, can be task-shifted. Khoza-Shangase (2021) argued that task-sharing, task-shifting and role release are important considerations given the human resource predicament in which South Africa finds itself. This author stressed, however, that clear minimum standards for training non-professionals would need to be established and clear and specific scopes of practice promulgated. This would ensure the protection of the public and prevent malpractice claims, which are a significant expenditure and undesirable in a resource-constrained context like South Africa, and it would have serious implications in a litigious-prone context like health and safety injuries compensation.

2.3.5. Burden of disease

Under pre-COVID-19 conditions, HIV is the greatest contributor to the burden of disease in South Africa and uses most of the health care budget. Health care resources and the budget are geared towards curbing mortality, with less attention directed to other health care issues – certainly quality of life conditions such as hearing loss. The country faces a quadruple burden of disease comprising maternal, newborn and child health; violence and injury; HIV and AIDS and TB; and noncommunicable diseases (Dlamini, Mququ & Hattingh 2016). In this quadruple burden, HIV, AIDS and TB have documented associations with hearing loss in isolation and have specifically been found to exacerbate ONIHL. Occupational noise-induced hearing loss does not occur in quarantine from other risk factors, including conditions such as HIV, AIDS and TB. Therefore, the South African mining industry must consider the impact that the burden of disease poses on the prevalence and management of ONIHL (Brits et al. 2012; Khoza-Shangase 2020a). Khoza-Shangase (2020a) accentuated that bearing in mind the burden of diseases on otology and audiology is key within HCPs because some of the diseases cause hearing loss, either as a primary cause, as a secondary or opportunistic cause or as an adverse effect of treatments for that disease. Consequently, the concomitant occurrence of these diseases and excessive noise exposure present an even greater challenge to HCPs if their relationship is not embedded into the conceptualisation, application and constant reviewing of HCPs. This is an important consideration for the South African context because of the number of people living with HIV, AIDS and or TB. Chapters 3 and 9 deliberate in more detail on risk factors for ONIHL in South African mines, including the influence of the burden of disease in HCPs within this context.

The most recent Joint United Nations Programme on HIV/AIDS (UNAIDS) estimates that there were 38 million people living with HIV in 2019, of whom 1.7 million were infected (UNAIDS 2020a). In 2019, approximately 690,000 AIDS-related deaths were documented worldwide, with a 39% decrease in AIDS-related mortality since 2010 (UNAIDS 2020a). South Africa, an LMIC, is reported to have among the highest HIV and AIDS prevalence rates globally, with the country being residence to one-fifth of people living with HIV worldwide (7.7 million people living with HIV) and has an HIV prevalence rate of 20.4% among adults (UNAIDS 2020b). National figures for South Africa reflected 200,000 new infections and 72 000 AIDS-related deaths in 2019 (UNAIDS 2020b). The 2018 *Global AIDS Update* reported on the progress towards the 90-90-90 targets, which aims to ensure that 90% of people living with HIV are aware of their status, that 90% of those who know their status are receiving treatment and that 90% of those on treatment are virally suppressed (UNAIDS 2020a). In 2019, globally, 81% of people living with HIV knew their status, and 82% were reported to be accessing treatment, with 88% of those accessing treatment virally suppressed (UNAIDS 2020a). In the same period, figures for South Africa reflect that 92% knew their status, with 70% of adults on antiretroviral treatment and 64% virally suppressed (UNAIDS 2020b).

A WHO (2020) report indicated a rise in the number of TB infections in South Africa, with more people falling ill with TB than previously believed. The WHO Global Tuberculosis Report 2020 revealed that approximately 360,000 individuals fell ill with TB in South Africa in 2019, a 20% surge when compared with the 2018 statistics where estimates reflected that 301,000 people fell ill with TB. This surge is incongruent with the reported global average that indicated a slight decline in TB infections from 2018 to 2019, although the 2019 global numbers estimate that 10 million people still fell ill with TB.

Despite the increased TB infection numbers in South Africa, the country's treatment plan remains impressive as reflected by the treatment success rate for drug-resistant TB, which is shown to have improved in this period (WHO 2020).

Stuckler et al. (2011, 2013) asserted that with South Africa being home to the highest numbers of individuals with HIV and AIDS and TB, the mining industry mirrors this. This reflection is because of the documented dramatic growth in TB that is correlated with the increased prevalence of HIV within the South African context (Chaisson & Martinson 2008). Reddy and Swanepoel (2006) maintained that around 30% of South African mineworkers acquire HIV in the first 18 months of being employed at the mines. AngloGold Ashanti (2012) also reported that their West Wits mining district recorded around 85% of their employees with a diagnosis of TB and HIV. The Minerals Council of South Africa (2020) confirmed that elevated levels of TB incidence in South Africa are traditionally strongly associated with mining, particularly gold mining. Reasons for this high incidence include (1) the concentration of employees in places of work and the high numbers of silicosis cases and (2) the rise in the HIV pandemic with its consequent outcomes for TB. Tracking of these numbers, including contact tracing, was made possible by the introduction of mobile and digital screening services in the early 2000s in gold mining companies. South African mines report declining TB rates since around 2008 because of the success of antiretroviral treatments that companies commenced rolling out in 2002. In 2014, through the MHSC, the South African mining industry committed to increasing its efforts to decrease TB incidence to become closer to or be lower than the South African TB incidence by 2024. Current findings reveal success with this commitment as numbers indicate that TB in the mines is at less than the expected incidence (Minerals Council South Africa 2020). Because of the known compounding influence of the synergistic impact of simultaneous noise and ototoxic medications for HIV and AIDS and or TB exposure (Khoza-Shangase 2020b; Valente, Hosford-Dunn & Roeser 2008), the consequences of this coexistence require exploration, valuation and discussion within HCPs.

These burdens of disease are some of the realities that HCPs must operate within in the South African mining context, as they do not exist in isolation from other challenges in the adult population, such as COVID-19, and are certainly in high prevalence in the South African mining population. HIV, AIDS and TB not only take up the lion's share of the budget but also contribute to the burden of hearing impairment in this population, including worsening the degree of hearing loss found in this population (Brits et al. 2012; Khoza-Shangase 2019, 2020b).

The current COVID-19 pandemic, as a burden of disease, also raises substantial challenges for the South African mining industry. Mbazima (2020) evaluated the effect that COVID-19 and its related lockdowns have on mining industries globally, with the creation of numerous scenarios through modelling. This author reported that high case numbers with the associated lockdown periods led to disproportionate increases in production across operations and commodities, with the anticipated 15%–25% less outputs than that of pre-COVID-19 expectations for 2020. Mbazima (2020) argued that outside the once-off destructive impact of the immediate shock of the lockdown on the South African mining industry, COVID-19 raises two extra key implications: (1) the mining industry must adapt to novel ways of operating and functioning to safeguard the OHS of workers – and these operational model modifications have already been started. These modifications occur within extra costs and complexities but are regarded as immutable for employee health and safety, as well as sustainable operations of the industry; and (2) considerable short-to-medium term uncertainty in commodities demand exists, and this is reliant on the recovery and easing up of lockdown restrictions that impact the global economy and the speed with which this happens (Mbazima 2020). With the discovery of new variants of COVID-19 and the slow vaccination drive, this anticipated progress will be significantly impacted.

2.3.6. Licence to operate, environmental compliance obligations, illicit and unlicensed mining and local grassroots activism

Sufficient media evidence exists that reveals a laboured and antagonistic relationship between the industry and the labour unions and mining communities (Mbazima 2020). Nupen (2020) expressed that recent court judgements in the cases of *Maledu and Others v Itereleng Bakgatla Mineral Resources* and the Xolobeni community's legal action against the Department of Mineral Resources and Energy of South Africa (DMRE) have underscored that the MPRDA is not supreme to the communities' rights to determine the fate of their land. This case is but one example of the strained and adversarial relationship between communities and industry. Recently, community unrests, protests and other challenges linked to mining licence to operate, illicit mining, environmental compliance requirements and local activism have been widely broadcasted, heightening investor risk sensitivities about South African mining, thus bolstering the 'risk premium' linked with investment in South African mining (Mbazima 2020). Mbazima (2020) asserted that beyond the 'perceived risks', actual challenges exist with health and safety, community empowerment and development, as well as other socio-economic goals that have not yet been met by the industry despite sincere commitment to do so. As part of the solutions offered, Mbazima (2020) recommended four best-practice initiatives aimed at ensuring the success of community development investments in this industry for all stakeholders, and these include (1) ensuring that community development plans are community-led and involve all relevant stakeholders, (2) amalgamation and organisation of community investment campaigns by individual mining companies where companies are in close proximity, (3) clearly outlining the community development plans with transparent tracking and reporting of key performance indicators (KPIs) and (4) ring-fencing a segment of mining royalties by the government to heighten development activities for those affected by mining activities such as mining communities. In line with what Khoza-Shangase (2020a) advocated within the mining industry, it is clear that for success and sustainability, with adherence to health and safety regulations, full, inclusive and continuous representation of all stakeholders is important within the South African mining industry. This representation must, however, include leadership and management by the regulatory authority, with representation from the special task force that is tasked with steering the executional certainty ship, as recommended by Mbazima (2020). Moreover, this must be external to and independent of the employer.

2.4. Recommendations

The presence of noise in any country, regardless of whether it is a HIC or not, has devastating effects (Moroe 2018). However, the impact becomes even more burdensome if a country is confronted by challenges such as the quadruple burden of disease, as is the case in South Africa (Khoza-Shangase 2020b; Yerramilli 2015). Therefore, in the presence of low education and literacy levels, low salaries, poor social determinants of health, poor OHS awareness and diseases such as HIV, AIDS and TB, ONIHL has a significant impact on the South African population and the State. The ripple effect from the employee involved to his or her family is profound. The effects are also significant for the employer as they incur costs through compensation for OHS claims, loss of productivity from health-related absenteeism, as well as loss of employees if an employee can no longer continue to work because of the ONIHL disability. The consequent costs to the State, which must step in with the provision of socio-economic grants, cannot be ignored. It is because of this reality that ONIHL is deemed one of the leading risks to the country's public health care and economy (Moroe 2018).

Therefore, the understanding of, and the embedding of, deliberations around ONIHL and HCPs within considerations around the various challenges facing South African mines is prudent and strategically forward-thinking. Deliberations, planning and strategising around regulations and legislation in mining should include health and safety that should also be of global standards, with the incorporation of recent advances in both prevention and treatment measures as far as occupational health conditions, such as ONIHL, are concerned. Concerns about global competitiveness of mines to meet the global demand and to be financially productive and sustainable should also consider the human capital and their quality of life. What Coulson (2018) claimed when he stated that economic growth, job creation and poverty alleviation tend to get more prioritised, at the expense of a safe and healthy workplace, should not continue unabated; striving for investment-competitiveness as an enabler for growth within the South African mining industry (Mbazima 2020) should also centralise best practice in terms of health and safety (hearing conservation). Occupational noise-induced hearing loss leads to restrictions on employment opportunities for the individuals affected, and therefore, HCPs contribute significantly towards the mining industry's employee empowerment goals, skills diversification and employee job performance.

Involvement of audiologists in the mining industry's deliberations around plans to address the impact of the global financial collapse on global demand, such as discussions around, for example, the exploration strategy that includes geological and geosciences solutions that are comparable to global best practice (Mbazima 2020) is key. Such strategies should, right from the beginning, embed health and safety considerations such as procurement of exploration equipment that falls under *buying quiet.* This can only happen if audiologists are represented in the recommended special task force, where implementation, coordination and systematic monitoring of plans and initiatives occur.

As far as regulatory and legislative uncertainty planning is concerned, audiologists should be involved in providing inputs and comments to regulations and legislation governing the mining industry, for example, the new BBBEEC for the South African Mining and Minerals Industry, 2018 ('the new Mining Charter'). When they do this, they will be ensuring that HCPs pillars such as engineering and administrative controls are embedded. Furthermore, audiologists' involvement in initiatives to address challenges confronting the mining industry would extend to the documented infrastructural challenges, particularly electricity supply. Infrastructural challenges would have significant influences on health and safety programmes as well. With energy supply uncertainty, certain HCP pillars such as medical surveillance and audiometric evaluations, employee and management education, motivation and training, periodic noise exposure measurement and monitoring, as well as risk-based medical examination (Amedofu 2007; Hong et al. 2013), would be negatively impacted, if they are not considered part of the overall strategic planning of the mining industry.

As far as labour uncertainty as a challenge is concerned, where Cawood (2011) highlighted the lack of balance between labour legislation and labour efficiency posing a threat to the South African mining industry, the author of this chapter further argues that the minimisation or side-lining of health and safety issues poses an even bigger threat. The South African MHSC stated one of its goals as 'every mineworker returning from work unharmed everyday: Striving for zero harm' (MHSC 2016). Striving towards this important goal while addressing all other labour challenges such as education, upskilling, career advancement, gender equality, salaries, accommodation, etc., should be centrally located on the mining industry's agenda. Furthermore, attracting and retaining skills that are lacking within the industry, skills that will facilitate meeting targets, including health and safety personnel such as audiologists, is an important strategic intervention by the mining industry. Hearing conservation programmes are part of the key strategies to contribute towards resolving labour uncertainties plaguing the industry. In the meanwhile, because of the documented capacity versus demand challenges in the South African audiology profession, innovative service delivery models such as the hybrid use of tele-audiology and task-shifting need urgent exploration (Khoza-Shangase & Moroe 2020b; Pillay et al. 2020).

Lastly, as far as the burden of disease is concerned, planning around identifying and managing the burden of disease conditions such as HIV, AIDS and TB has significant implications for HCPs. Sufficient evidence exists on the impact of these conditions and their treatments on hearing function. Therefore, the mining industry's initiatives around them should be comprehensive, allowing for programmatic inclusion of HCPs – where medical surveillance and audiometric evaluations, risk-based medical examination and record-keeping pillars of HCPs can be embedded. Ntlhakana et al. (2020) recommended an inclusive, integrative and proactive data management system that incorporates data such as ages, occupations and mineworkers' noise exposure levels and medical surveillance information that includes medical treatments for burdens of disease, because these are significant risk indicators for ONIHL, especially within the South African context. Such an integrative and proactive data management system should comply with ethical standards around data management as well as the PoPIA (Ntlhakana et al. 2021). Coronavirus disease 2019 also calls for a revisit of direct employee contact for HCP implementation, with telehealth and telet-raining requiring serious considerations. Planning around this can form part of the mining industry's community development and empowerment initiatives. It can also be part of other socio-economic objectives that involve training members of the community around each mine to perform task-shifting duties under the management of the audiologist contracted to the mine.

■ 2.5. Conclusion

Given that HCPs are one of the key aspects of health and safety within the South African mining industry, it is important to consider the realities of the South African mining industry to ensure implementation that is contextually relevant and responsive. This chapter addressed the challenges faced by

South African mines where HCPs must be implemented. The chapter suggested that HCPs should be cognisant of these realities and how they impact each other, with a strong recommendation of cohesive, comprehensive and integrated strategies in addressing the challenges – strategies that embed health and safety centrally and not peripherally. An overview was provided of the South African mining context and the realities that need to be confronted when considering HCPs' nonimplementation and or lack of success in meeting the milestones in relation to competing priorities, such as the global economic collapse and its impact on global demand, uncertainty surrounding regulations and legislation, infrastructure challenges, workforce uncertainty, burden of disease, licence to operate, environmental compliance obligations, illicit and unlicensed mining and local grassroots activism. The chapter concluded by offering recommendations for HCPs initiatives that are sensitive to and aware of South African contextual realities.

Chapter 3

Risk factors for occupational noise-induced hearing loss in African mines: Arguing for contextualisation

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3.1. Introduction

Occupational noise-induced hearing loss is an occupational health condition that is reported to present as a major threat to the well-being and health of workers exposed to excessive noise. Chen, Su and Chen (2020) asserted that occupational noise exposure endangers the hearing function of many employees and has numerous documented adverse effects on their well-being, with fatigue, insomnia, irritability and ONIHL being some of these. Occupational noise-induced hearing loss, as an adverse effect, has a limiting impact on the affected individual's communication, which in turn causes psychosocial consequences such as poor personal attention, poor interpersonal relationships, raised stress levels, sadness and anxiety, reduced self-confidence, poor sense of individuality and impaired cognition (Basner et al. 2014;

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Chen et al. 2020; Masterson et al. 2016). Older individuals with a mild degree of hearing loss have been found to have a twofold elevated risk of dementia, with this risk increasing exponentially to fivefold when the degree of the hearing loss is severe (Lin 2012). Because ONIHL is a complex but preventable condition (Amjad-Sardrudi et al. 2012; Seixas et al. 2011), a careful and clear understanding of the pathogenesis or the risk factors for this condition is crucial to develop efficient preventive measures. The availability of such preventive measures is particularly relevant in LMICs such as South Africa, where primary prevention is the State's adopted health care strategy. Therefore, this chapter explores the documented pathogenesis and risk factors of ONIHL, contextualising these within the African context, to guide preventive measures in African mines, with South Africa often used as a case study. The evidence reviewed in this chapter provides guidance to the African mining industry, audiology community and policymakers with regard to the allocation and prioritisation of resources for best preventive outcomes. This is done for both future planning and reflection on the effectiveness of past interventions. Intervention strategies within HCPs should take careful cognisance of this evidence to allow for the implementation of contextually relevant and responsive preventive programmes.

Zhang et al. (2019) reported that noise-induced hearing loss (NIHL) is a universal occupational health risk and the second most common type of sensorineural hearing loss (SNHL), with presbycusis being first (Sliwinska-Kowalska & Zaborowski 2017). Vos et al. (2012) estimated that 1.3 billion individuals have NIHL. Globally, reports indicate that, in adults, occupational noise exposure causes 16% of cases of disabling hearing loss (Kerr et al. 2017; Nelson et al. 2005; Vos et al. 2012). This presentation of NIHL is reported to be in a higher proportion in males (22%) than in females (11%), and this is argued to be because of gendered occupational categories and working lifetimes (Concha-Barrientos, Campbell-Lendrum & Steenland 2004). Age-wise, Concha-Barrientos et al. (2004) reported that almost 90% of these cases are in the 15–59-years-old age group, with the rest over 60-years-old. This number signifies that although ONIHL does not directly produce early mortality, it does significantly contribute towards substantial disability globally, thus inducing significant morbidity through deafness. The last estimates for sub-Saharan Africa for the period 2016–2017 on occupational health in the mining sector indicated that hearing loss accounted for 18% of the burden of injury among ex-mineworkers in South Africa, Lesotho, Swaziland and Mozambique (Osewe & Nkrumah 2018).

Global evidence indicates that occupational noise exposure produces immense disease and economic burden to both the individual affected and the society as a whole (Chen et al. 2020). Economically, for example, in the United States of America (USA), the annual compensation for ONIHL has been approximated at US$242.4m, and this economic burden is reportedly continuously rising (Basner et al. 2014; Vos et al. 2012). Organisations such as the WHO and the National Institute for Occupational Safety and Health (NIOSH) have categorised NIHL as a disorder requiring high priority by the research community, and this includes investigations into factors influencing individual susceptibility to NIHL.

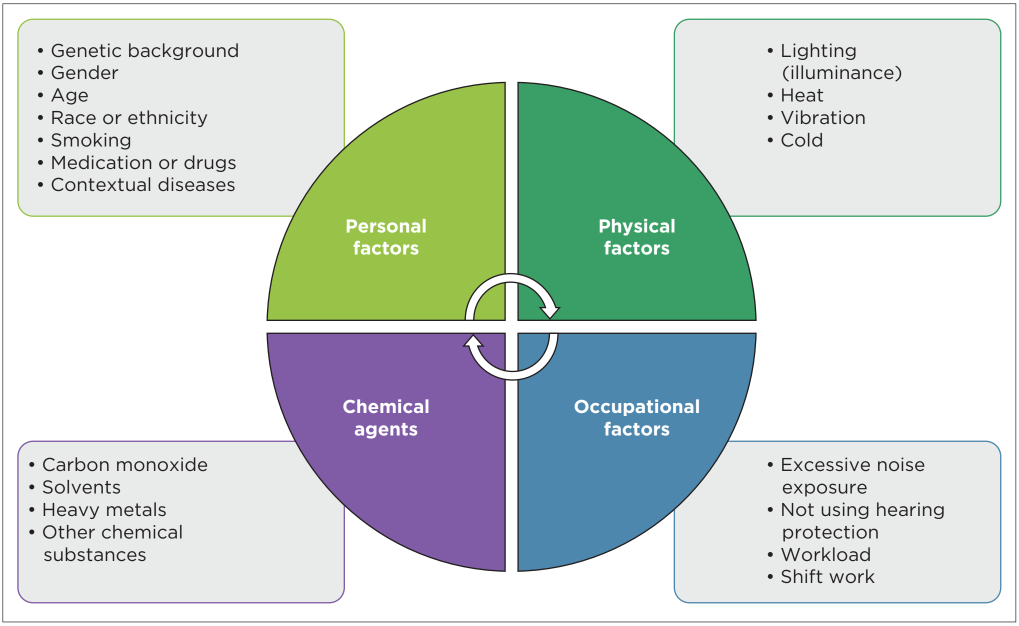
Over and above the noise exposure at work, numerous other factors impact individual susceptibility to NIHL (Hong & Kim 2001; Le et al. 2017; Zhang et al. 2019). Young et al. (2011) asserted that recurring noise exposure, commencing at 4 kHz, destroys the sensitive structure of the inner ear, leading to NIHL. Once this damage has occurred and hearing is impaired, it is impossible to restore it, hence the importance of reducing risk factors as the best preventive approach for NIHL (Zenz, Dickerson & Horvath 1994). As evidence proves that over and above the effect that variability in exposure conditions has on individuals exposed to occupational noise, some biological factors documented to impact workers' susceptibility to the effects of noise also exist. This highlights the need for workers to be well protected as the measurement of exact susceptibility per worker might be impossible (NIOSH 2018; Sliwinska-Kowalska & Davis 2012). Regardless of the quantity of noise exposure that each worker is subjected to, some workers are more susceptible to developing NIHL than others with the same exposure (Daniel 2007; Sliwinska-Kowalska et al. 2005).

The ONIHL risk factors have been categorised in different ways by various researchers. For example, NIOSH (2018) grouped these factors into biological factors, such as typical health challenges, age, gender, race or ethnicity and hereditary factors, while Chen et al. (2020) described them under environmental versus host factors (both genetic and acquired). Daniel (2007) defined these factors as falling under nonmodifiable factors (external to one's control) or modifiable factors (within one's control). Nonmodifiable factors include genetics (Daniel 2007), increasing age (Daniel 2007; Dobie 2001; Kerketta, Gartia & Bagh 2012; Pyykkö et al. 2007; Rosenhall 2003; Toppila, Pyykkö & Starck 2001), race (Cunningham & Norris 1982; Daniel 2007; De Koker et al. 2003; Pyykkö et al. 2007) and male gender (Daniel 2007; Ecob et al. 2008; Guimaraes et al. 2004; Kilicdag et al. 2004; Pratt et al. 2009). Modifiable factors include intentional exposure to excessive noise, not using hearing protection (Daniel 2007; Marlenga et al. 2012), smoking (Daniel 2007; Ecob et al. 2008; Fabry et al. 2010; Ferrite & Santana 2005; Liu et al. 2008; Sharabi et al. 2002), ototoxic agents (Kirchner et al. 2012; Liu et al. 2008; Sliwinska-Kowalska et al. 2006), ototoxic drugs (prescribed for the treatment of diseases like HIV and AIDS, TB and cancer) (Assuiti et al. 2013; Arslan, Orzan & Santarelli 1999; Campo, Morata & Hong 2013; Khoza-Shangase, 2010, 2013; Khoza-Shangase, Mupawose & Mlangeni 2009; Li & Steyger 2009; Schellack & Naude 2013) and the presence of diabetes and cardiovascular disease (Daniel 2007).

Recently, Golmohammadi and Darvishi (2019) categorised risk factors into four groups, with a total of 16 factors, and these four groups are listed as follows:

1. personal factors (age; gender; genetic predisposition or heredity; smoking; medication and drugs; contextual diseases such as diabetes, cardiovascular diseases and hypertension; and elevated cholesterol and triglycerides levels)
2. chemical agents (heavy metals, solvents, carbon monoxide [CO]), other chemical substances such as organophosphorous pesticides, ototoxic chemicals (cyanides, phosphorous compounds and hydrogen cyanide [HCN]) and epoxy adhesive
3. physical factors (lighting – illuminance, heat, vibration and cold)
4. occupational factors (workload and shift work).

The afore-presented risk factors pose a significant challenge to people exposed to occupational noise because of the negative impact that they exert on health and safety, as well as the ear health care of individuals exposed to hazardous noise. Chen et al. (2020) highlighted that the interaction between host (both acquired and hereditary) and environmental factors presents a complex mechanism of ONIHL, emphasising the importance of preventive measures aimed at decreasing the morbidity of ONIHL in workers. This chapter adopts Golmohammadi and Darvishi's (2019) four categories of approach in comprehensively reviewing risk factors for ONIHL, as depicted in Figure 3.1.



Source: Author's own work.

FIGURE 3.1: Quadruple risks for ONIHL.

Concha-Barrientos et al. (2004) contended that because of the continued lack of ability to quantify the health effects of occupational risk factors, despite the growing importance of objective measurements, policymakers progressively depend on assessments of the disease burden of risk factors and the manner in which the burden is spread by socio-economic status. This approach is adopted to establish efficient interventions and cogent policies that are appropriate for the context. This position highlights the value of understanding risk factors for any burden of disease, such as ONIHL, one of the most evident examples of a health risk that has been underrated (WHO 2010).

3.2. The four groups categorising risk factors for ONIHL

Kanji and Khoza-Shangase (2019), in their work on preventive audiology in the South African paediatric population, highlighted the importance of context itself as a risk indicator for hearing impairment. These authors proposed the concept of a quadruple influence on risk, which acknowledges the impact of the burden of disease, medical advancements, technological advancements and human advancements – in early detection and intervention. This concept of quadruple influence on risk is solidified in Khoza-Shangase and Kanji (2021) where the authors stress the importance of consistently considering the contextual influence of risk factors on hearing impairment. The author of this chapter considers this an important concept to bear in mind in debates and discussions about the following risk factors for ONIHL in African mines, as depicted in Figure 3.1.

3.2.1. Personal factors

The personal factors that are reviewed in this chapter include genetic background (genetic predisposition or heredity factors), male gender, increasing age, race or ethnicity, smoking, medication or drugs (ototoxicity) contextual diseases (general health issues) such as diabetes, elevated cholesterol and triglycerides, cardiovascular diseases and hypertension.

3.2.1.1. Genetic background (genetic predisposition or hereditary factors)

Substantial headway has been made in understanding factors that predispose individuals to NIHL, other than chronic exposure to noise. Bowens (2018a) provided an update on risk factors for ONIHL by maintaining that this disorder originates from a complex interaction of environmental and hereditary (genetic) factors, with some investigators estimating that genetic causes may be responsible for approximately 50% of hearing loss variability post–noise exposure (Sliwinska-Kowalska & Davis 2012; Zhang et al. 2019). The complex genetic-environmental factors interaction with noise exposure includes other risk factors such as medication, solvents and vibration, as well as lifestyle factors (e.g. alcohol consumption and smoking) (Konings, Van Laer & Van Camp 2009a; Liu et al. 2008; Sliwinska-Kowalska & Pawelczyk 2013).

Synaptic excitotoxicity and oxidative stress have been reported to be the chief mechanisms of morphological pathologies in damage to the sensory cells and outer hair cells of the cochlear found in NIHL (Henderson et al. 2006; Pilati et al. 2012). Nonetheless, despite this clear mechanism, evidence indicates that under the same noise exposure levels, employees may experience different levels of hearing loss. Bowens (2018a) argued that these differences denote the significant role that genetic susceptibility plays in the incidence of NIHL.

In the aforementioned update, Bowens (2018a) noted three key recent updates:

1. Firstly, the increased amount of recent evidence on hereditary factors and their links to NIHL implies potential associations between variants in several genes (e.g. heat shock protein 70) and predisposition to NIHL.
2. Secondly, approximately 70%–80% of genetic hearing loss is projected to be nonsyndromic in nature. Depending on inheritance pattern, there are four main types, with variations found between and within types in the age of onset, progression and severity. Furthermore, autosomal recessive forms (75%–80%) are more frequent; however, the autosomal dominant forms (20%–25%) commonly occur in adulthood and advance with age. Therefore, in this case, some forms are challenging to differentiate from presbycusis.
3. Thirdly, although causes of adult-onset syndromic hearing loss are rare, there is a broad range of inherited syndromes, as well as numerous other conditions, that may contain an inherited component such as cardiovascular disease and diabetes that cause hearing impairment with other signs and symptoms.

These updates indicate significant advancement in knowledge on genetic factors as a risk factor for NIHL. Recently, Zhang et al. (2019) conducted a study where the objective was to screen for NIHL-associated single-nucleotide polymorphisms (SNPs) and to create genetic risk prediction models for NIHL in a Chinese population. Findings from this study revealed seven SNPs in the *CDH23*, *PCDH15*, *EYA4*, *MYO1A*, *KCNMA1* and *OTOG* genes that were significantly ($p < 0.05$) linked to the risk of NIHL, with additional seven SNPs that had a marginal ($p > 0.05$ and $p < 0.1$) association. These authors conclude that genetic susceptibility has a significant role in the incidence of NIHL and that genetic risk score (GRS) values may be used in the determination of predisposition to NIHL and in the assessment of genetic risk for NIHL. In an earlier study, Konings et al. (2009b) conducted an association study for NIHL grounded on a candidate gene approach, where 644 SNPs were examined in 53 candidate genes in two independent NIHL samples. Their findings, although not conclusive as replication in independent samples was required, also suggested that *MYH14* may be an NIHL susceptibility gene.

Although this association has been established internationally, a paucity of research in African populations exists; therefore, implications for future research on this risk factor within the African context. Yousaf, Friedman and Riazuddin (2016) highlighted the importance of contextual studies investigating genetic influences on hearing impairment as they argued that the identification of genetic modifiers that can play a fundamental function in modifying the rate and or severity of hearing impairment can provide important 'insights into the complex molecular and functional networks essential for sound transduction and might reveal novel targets for potential therapeutic interventions to circumvent hearing loss' (Yousaf et al. 2016, p. 73).

Lebeko et al. (2015) suggested that next-generation sequencing (NGS) be utilised as an approach to explore genetic links to hearing loss. This is as opposed to using the routinely used Sanger sequencing, which is known to be expensive and time-consuming. These authors argued that this would be better able to resolve autosomal recessive nonsyndromic hearing loss (ARNSHL) among sub-Saharan African patients, where more than 60 genes have been linked to ARNSHL. Although this is advised for general hearing loss, a similar approach could be adopted for ONIHL genetic factor exploration. Wonkam Tingang et al. (2020) found that hereditary hearing impairment comprises 0.8%–14.8% of all cases in an African population. In 32.6%–37% of hearing impairment cases, the cause remains undiscovered. These authors reported that nonsyndromic hearing impairment (NSHI) is the leading cause and is responsible for 86.1%–92.5% of cases of hearing impairment of genetic origin in this population. Usher and Waardenburg syndromes are credited for 8.9%–42.9% and 50%–57.14% of genetic syndromic cases, respectively.

3.2.1.2. Male gender

There is a paucity of evidence that focuses on gender as a risk factor for ONIHL; however, few studies have argued that gender is probably an effective factor (Cruickshanks et al. 1998; Golmohammadi & Darvishi 2019; Lie et al. 2016; Nash et al. 2011). Golmohammadi and Darvishi (2019) discussed two cross-sectional studies by Cruickshanks et al. (1998) and Nash et al. (2011), where findings revealed an association between occupational noise exposure and male gender. Another study by Helfer (2011) found that males had a higher occurrence of hearing loss than females following the same exposure to noise louder than 85 dB(A). Using South Africa as a case study, although the South

African population is 51.1% female (StatsSA 2020), the South African mining industry is male-dominated, with females only representing 12% of the mining labour force (Minerals Council of South Africa 2019). Therefore, gender as a risk factor has significant implications for the South African mining industry, which is male-dominated.

☐ 3.2.1.3. Increasing age

Golmohammadi and Darvishi (2019) claimed that the interaction effect between aging and noise exposure on NIHL is complex and that it could be additive in nature. These authors stated that age-related hearing loss (ARHL) increases with age, while the onset of NIHL follows approximately three to five years of excessive noise exposure, with NIHL not increasing to the same degree in older individuals as it does in younger individuals, because older individuals already present with presbycusis (ARHL). Rubak et al. (2006) reported that the risk of hearing loss, in their study, was > 20 dB higher in workers with more than 20 years of noise exposure when compared to those with less than 20 years of exposure.

Toppila et al. (2001) investigated the impact of age, noise and confounders in NIHL, where they found that the older participants were more predisposed to NIHL than the younger ones where participants were matched by exposure, age, serum cholesterol and blood pressure level. These authors also found that factors related to age (independently but causally) were significant in the development of NIHL in employees exposed to noise levels at levels below 98 dB(A). Generally, evidence suggests that the mean hearing thresholds at 4 kHz and 8 kHz are significantly higher as the age and work experience increase (Golmohammadi et al. 2013; Hederstierna & Rosenhall 2016; Somma et al. 2008). Pelders and Nelson (2019) reported on the demographic profile of South African mineworkers to reflect an average age of 38 (± 9) years, ranging from 20–65-years-old. Therefore, this presents the mining industry's vulnerability to advancing age as a risk factor for ONIHL in this population.

☐ 3.2.1.4. Race and ethnicity

Strauss et al. (2014) highlighted that race has been demonstrated to be an important factor in establishing susceptibility to NIHL and ARHL. In their study, these authors found that median thresholds at 500 Hz and 4 kHz were 5 dB worse in white males than in black males. Their findings are explained by the fact that race has been labelled as a proxy factor for inherent systematic differences in predisposition to NIHL or ARHL. Where noise exposure is eliminated, numerous studies have reported hearing to present with better hearing thresholds in black versus white participants in individuals with normal hearing (Dreisbach et al. 2007; Flamme, Deiters & Needham 2011; Henselman et al. 1995). As cited in Strauss et al. (2014), Bunch and Raiford (1931) reported on better hearing thresholds in black noise-exposed participants when compared with their white counterparts. Ishii and Talbott (1998) and Henselman et al. (1995) also described similar findings in noise-exposed participants in high frequencies. Epidemiologic investigations of hearing loss in adults have illustrated that this phenomenon of hearing loss being significantly lower in black people than in white people is because of skin pigmentation as a marker of melanocytic functioning (Lin et al. 2012). Lin et al. (2012) claimed that this reconciles the perceived association and that skin pigmentation is linked to hearing impairment detached from race or ethnicity. Klopper et al. (2019) argued that the inner ear melanin amount modulates the endocochlear potential and offers an otoprotective effect. Murillo-Cuesta et al. (2010) found that when compared with transgenic mice, young albino mice exhibited an elevated prevalence of profound SNHL with a lesser recovery of hearing thresholds following excessive exposure to noise. This study established a relationship with the lack of cochlear melanin. The aforementioned evidence requires careful consideration within the African mining industry that comprises a large majority of the black African workforce.

☐ 3.2.1.5. Smoking

Numerous studies have revealed that cigarette smoking potentially negatively affects hearing function (Dudarewicz et al. 2010; Farhadian, Aliabadi & Darvishi et al. 2015; Liu et al. 2008; Starck, Toppila & Pyykkö 1999). This effect is either interactive or additive (Ferrite, Santana & Marshall 2013; Mofateh et al. 2017; Mohammadi et al. 2010a; Sung et al. 2013; Tao et al. 2013; Zamanian et al. 2013). Tao et al. (2013) investigated the relationship between smoking and noise in the development of hearing impairment and also sought to establish the degree of influence that smoking has on NIHL. Their findings suggested that smoking significantly negatively influences NIHL in workers exposed to excessive occupational noise, with high frequencies (4 000 Hz and 6 000 Hz) being significantly worse in smokers than non-smokers exposed to noise where the length of exposure was longer than 10 years. These adverse findings were absent where the length of exposure to noise was less than 10 years. Findings from this study seem to confirm that (1) compared with non-smokers, under similar occupational noise exposure, smokers possess an elevated risk of high-frequency hearing loss and (2) the interaction between excessive noise exposure and cigarette smoking is additive in nature. Toppila et al. (2000) found that individuals who had never smoked before had substantially better hearing thresholds at 4 kHz than smokers, and Liu et al. (2008) also found that smoking was significantly associated with NIHL ($p < 0.05$). In a meta-analysis of observational studies, Li et al. (2020) synthesised previous findings from published observational studies to elucidate the relationship between NIHL and smoking. These authors discovered a linear-curve association between the risk of NIHL and higher numbers of packages per day in smoking years (pack-years). Where the number of pack-years was less than 15, the risk of NIHL was lower. Additionally, this study revealed that quitting smoking can reduce the risk of NIHL, that current smokers have an increased risk than previous smokers and that there is a positive dose-response relationship between NIHL and smoking, with smoking aggravating the development of NIHL (Barone et al. 1987; Mehrparvar et al. 2015; Mizoue, Miyamoto & Shimizu 2003; Uchida et al. 2005; Wild, Brewster & Banerjee 2005). With the 2017 National Survey indicating that approximately 20% of South Africa's adult population (15-years-old and above) are cigarette smokers (Southern Africa Labour and Development Research Unit 2018), with about 44 000 South Africans dying from tobacco-related diseases every year (Groenewald et al. 2007), smoking as a risk factor for ONIHL is an important ototoxicant for the South African mining industry to consider in their preventive strategies.

☐ 3.2.1.6. Medication and drugs (ototoxicity)

Several medications have been documented to be ototoxic in nature, causing cochlear and or vestibular damage (Chen et al. 2020; Golmohammadi & Darvishi 2019; Khoza-Shangase 2017). Certain aminoglycosides such as gentamicin and kanamycin, as well as antineoplastic drugs such as cisplatin, are known to be ototoxic (Collins & Twine 1985). Limited studies exist on the combined effects of noise exposure and drugs in humans, with the preponderance of available evidence being on experimental work on laboratory animals. The available evidence reveals a prominent synergistic effect between noise and ototoxicity (Bombard, Campo & Lataye 2005; Collins 1988; De Jong et al. 2012; Gannon, Tso & Chung 1979; Ryan & Bone 1982; Tan et al. 2001; Vernon et al. 1978). Recently, Khoza-Shangase (2020) investigated the co-occurrence of ototoxicity and noise exposure in a group of gold mineworkers with and without a history of TB in South Africa. Because of the high prevalence of co-existing tuberculosis and HIV (UNAIDS 2020), and as an association exists between treatments for TB, HIV and AIDS and ototoxicity, concurrent exposure to other ototoxins such as excessive noise requires careful investigation within this context. Findings from this study indicate that gold mineworkers with a TB treatment history present with worse hearing thresholds in the high frequencies than those without this history. This author concluded that these study outcomes stress the significance of considered HCPs, where monitoring for ototoxicity forms part of the preventive programmes, and intensive work around the prescription of oto-protective or chemo-protective agents is an urgent need in this population.

☐ 3.2.1.7. Contextual diseases

Contextual diseases such as diabetes, cardiovascular diseases and hypertension, as well as elevated cholesterol and triglycerides, have been documented to aggravate hearing loss, with hearing loss also being recognised to worsen these burdens of diseases (Golmohammadi & Darvishi 2019; Ishii et al. 1992; Lie et al. 2016). Studies have found a significant association between these listed conditions and NIHL (Agrawal, Platz & Niparko 2009; Fransen et al. 2008; Fuortes et al. 1995; Ishii et al. 1992; Yoshioka et al. 2010), where these conditions have been discovered to intensify the adverse effects of noise and worsen NIHL. Golmohammadi and Darvishi (2019) recommended further longitudinal investigations through the interaction effects of contextual diseases at workplaces. Within the South African context, Khoza-Shangase (2020) proposed the same, particularly with the documented high incidence of TB and HIV and AIDS within the mining industry. Chapter 2 provides a discussion on the reality of HIV, AIDS and TB within the South African mining context, with Chapter 9 detailing this burden of disease and its influence on ONIHL and HCPs.

South Africa is documented to face a quadruple burden of disease resulting from (1) injury and trauma; (2) noncommunicable diseases such as hypertension and cardiovascular diseases, diabetes, cancer, mental illnesses and chronic lung diseases like asthma; (3) maternal and child mortality; and (4) communicable diseases such as HIV, AIDS and TB (WHO 2018). The South African mining industry's preventive intervention efforts around this quadruple burden of disease should also be stimulated by some of these and or their treatments having documented impact on ONIHL.

3.2.2. Chemical agents

The influence of environmental agents occurring concurrently with noise, even at relatively low-intensity levels, has been reported as a risk factor for significant hearing loss that is worth recognising (Fechter, Chen & Rao 2002; Manning & Pillay 2020; Pillay 2020). Fechter et al. (2002) contended that the adverse effects of noise on hearing can be substantially altered by additional exposure to chemical agents that may or may not solely be ototoxic in nature. There is evidence suggesting that damage to the auditory pathway can be caused by exposure to an extensive variety of chemical and drug exposures, in addition to noise exposure (Fechter & Liu 1997; Rybak 1986, 1992). Chemical agents including solvents, CO and heavy metals; other chemical substances such as organophosphorous pesticides; ototoxic chemicals such as phosphorous compounds, cyanides and HCN; and epoxy adhesive are implicated (Niranjan 2014). Cochlear impairment because of noise exposure alone is predictable; however, gaps in evidence exist regarding ONIHL following or alongside chemical exposure. This highlights the importance of research in this area, particularly in the African context where there are increasing efforts to see effective hearing preventive programmes in mines, efforts that call for careful monitoring of all relevant risks and risk interactions (Khoza-Shangase, Moroe & Edwards 2020; Manning & Pillay 2020; Ntlhakana et al. 2021; Pillay 2020).

Manning and Pillay (2020) argued that such preventive efforts, within the South African context, also require regulatory and legislative support. In a critical analysis of contemporary South African occupational health law and hearing loss, these researchers found numerous features that brand the set of applicable South African legal frameworks unequal when it comes to chemical agents and ONIHL, with two of these being relevant to the current discussion. These researchers found that:

1. Hazardous Biological Agents Regulations (Republic of South Africa 2001), Hazardous Chemical Substances Regulations (HCSR) (Republic of South Africa 1995) and the Lead Regulations (2001) omit ototoxicity in their coverage of medical surveillance standards despite documented ototoxic agents, for instance, lead, solvents and infectious agents. Furthermore, regulations such as Construction (Republic of South Africa 2014) and National Road Traffic Regulations (Republic of South Africa 2000) lack medical fitness standards, although medical certification is a requirement. These authors frown upon this omission, particularly because they argue that both of these work contexts utilise documented ototoxic agents such as solvents and CO.
2. Regulations appear to highlight the influence of noise, at the minimisation of the impact of ototoxic agents. Manning and Pillay (2020) argued that there are sector inequalities that are present, where employees in noisy environments benefit from legislation such as the Noise-Induced Hearing Loss Regulations (NIHLR), without comparable benefits for employees exposed to ototoxic agents.

Manning and Pillay's (2020) critical analysis of legislation and regulations within the South African context concluded by averring that the prevailing narrative in these documents is one of the necessity to control excessive exposure to *noise* to prevent *hearing loss*, disregarding firm evidence that shows that chemical agents, in the presence of noise, also affect workers' hearing (Watts 2019). These authors therefore asserted that the univocal epistemology that leads the legal discourse in the South African context represents an infringement of workers' rights by being selectively protective, where workers exposed to chemicals are excluded from ear-and-hearing protection, thus adhering to laws that tacitly discriminate worker rights. 'Indirect discrimination is the violation of one's rights to equal protection because the existing policy disfavours a particular group, without justification' (Manning & Pillay 2020, p. 5). Therefore, Pillay (2020) suggested that chemical exposure leading to ototoxicity in South African workplaces should be seen as a fresh challenge for occupational health care research and preventive initiatives, hence the importance of deliberating on the available evidence on chemical agents as a risk factor for ONIHL within South African mines. Currently, there are gaps in South African governmental policies, with OHL being exclusively aligned to noise as the only causative agent, at the exclusion of chemical ototoxicity in them; therefore, exploring evidence of this toxin in OHL will have a significant impact on HCPs (Moroe et al. 2018; Pillay 2020). Internationally, however, NIOSH and the Hearing Conservation Committee (American College of Occupational and Environmental Medicine) have suggested risk assessment for exposure to ototoxic drugs and chemical substances and hearing protection programmes (Hearing Conservation Committee 2003), while Occupational Safety and Health Administration (OSHA) has also proposed hearing assessment of employees with regular exposure to ototoxic medications (OSHA 2002).

Golmohammadi and Darvishi (2019) grouped chemical agents that potentiate ONIHL into four groups, for which Fechter et al. (2002) provided an overview of environmental agents that serve as potentiation for ONIHL. These are as follows:

1. CO – which falls under chemical asphyxiants (Chen, McWilliams & Fechter 1999; Chen & Fechter 1999; Fechter 1989; Fechter, Young & Carlisle 1988; Young et al. 1987)
2. organic solvents (Campo et al. 1997; Crofton, Lassiter & Rebert 1994; Crofton & Zhao 1994; Fechter et al. 1998; Johnson et al. 1988; Morata et al. 1993, 1997a, 1997b; Morata, Dunn & Sieber 1994)
3. heavy metals (Fechter et al. 1992; Rice & Gilbert 1992; Wu et al. 1985)
4. other chemicals.

Fechter et al. (2002) highlighted that concurrent and even consecutive exposure to noise and some of these environmental chemical agents can significantly increase predisposition to NIHL (Chen & Fechter 1999; Fechter et al. 1988; Johnson et al. 1988, 1990; Johnson 1993; Lataye & Campo 1997; Morata et al. 1993), and this is the conclusion of the systematic review by Golmohammadi and Darvishi (2019), where combined effects of other risk factors and occupational noise exposure were appraised.

Significant research is still required to expound on the mechanisms that account for chemical ototoxicity; however, sufficient data linking cochlear function to oxygen delivery raise the necessity to concentrate on the manner in which noise and chemical asphyxiants interact to cause permanent hearing disruption, at least in laboratory animal models (Fechter et al. 2002). Fechter et al. (2002) found that low to moderate exposure levels of HCN and CO can potentiate NIHL, with other studies indicating that CO leads to cochlear hypoxia, particularly in the basal region (hence high-frequency hearing loss) (Chen et al. 1999). The International Commission on Biological Effects of Noise

(ICBEN) reported that CO worsens ONIHL (Leroux & Klaeboe 2012), with findings from Lacerda, Leroux and Gagn (2005) also confirming this. Fechter et al. (2002) presented evidence showing that free oxygen radicals may be accountable for NIHL potentiation by chemical asphyxiants. An additional basis for investigating noise and chemical asphyxiants interaction is the frequency of use of these chemicals in several diverse workplace contexts.

As far as organic solvents are concerned, available evidence has exposed an association between solvents and hearing loss (Fuente & McPherson 2007; Fuente et al. 2009), as well as a synergistic impact of noise and solvents on the auditory system (Chang et al. 2003, 2006; Jacobsen et al. 1993; Kim et al. 2005; Lobato et al. 2014; Metwally et al. 2012; Mohammadi, Labbafinejad & Attarchi 2010b; Morata et al. 1993; Pourzarea et al. 2016; Sliwinska-Kowalska et al. 2003, 2004; Unlu et al. 2014), where the preponderance of the evidence concludes that concurrent exposure to solvents exacerbates ONIHL.

Bowens (2018b) provided an update on a 2010 review of evidence on risk factors for ONIHL, with a focus on exposure to solvents with or without noise. The overall conclusion from this review is that the risk of hearing loss increases with the total number of diverse solvents that the individual has been exposed to, as well as with the degree and length of exposure. The 2010 review, as detailed by Bowens (2018b), concluded the following with regard to solvent exposure:

- Exposure to solvents seemed to present as a risk for hearing loss.
- Styrene exposure, at reasonably low levels, was associated with ONIHL at low noise exposure levels.
- Combined solvent (i.e. styrene and toluene) and noise exposure may pose a greater risk to hearing function than individual factor exposure.
- There was no uniformity in the configuration of the audiogram with solvents, with some solvents (e.g. toluene) causing hearing loss at lower frequencies (0.5 kHz, 1 kHz and 2 kHz) while others (e.g. styrene) affecting high frequencies (6 kHz–8 kHz), atypical to the NIHL found in working-age people.

The 2018 update review highlighted that, of the three key solvents of concern, toluene and styrene are the most ototoxic, with xylene (i.e. the p-xylene isomer) being the least, with styrene and toluene found to have synergistic effects with noise. Currently, there is a paucity of evidence on the synergistic effects of xylene (Bowens 2018b). In this review, Bowens (2018b) also found that currently, there are no endorsed clinical measures to evaluate hearing loss connected to solvent exposure, but highlighted that certain international agencies have produced guidelines on evaluating and monitoring hearing function in employees exposed to ototoxic solvents, whether in the presence or absence of excessive noise levels. The NIOSH (2018) reported on the NIOSH and OSHA co-copyrighted publication that addresses hearing impairment because of noise and chemicals exposures. This document offers information on occupations and industries where ototoxicants are most likely utilised, substances and chemicals that have ototoxicants, as well as proposals for regulating and preventing exposures. The NIOSH (Criteria document) and the American College of Occupational and Environmental Medicine American College of Occupational and Environmental Medicine (Loss 2003) recommended that HCPs consider chemical exposures when regulating exposures, evaluating hearing and monitoring risks.

Similar to outcomes from studies on solvents, exposure to heavy metals has been shown to increase the risk for ONIHL (Prasher 2009), with lead (Bleecker et al. 2003; Farahat et al. 1997; Forst, Freels & Persky 1997; Hwang et al. 2009; Wu et al. 2000), mercury (Discalzi et al. 1993; Shlomo et al. 2002), cadmium (Choi et al. 2012; Ozcaglar et al. 2001) and arsenic documented to more likely exacerbate occupational noise exposure effects (Golmohammadi & Darvishi 2019; Phaneuf & Hetu 1990). Other chemical substances that have been highlighted as risk factors for ONIHL include organophosphorous pesticides (Mac Crawford et al. 2008) and epoxy adhesive (Yang, Shie & Chen 2016).

Utembe et al. (2015) maintained that while mining occupies a leading role in the South African economy, its links to numerous chemical hazards such as cyanide, mercury, diesel particulate, platinum, manganese, vanadium and chromium and requires that the mining industry goes beyond adopting occupational exposure limits (OELs) for some hazards from other countries. This author recommended that the country should preferably establish its own standards based on local toxicity investigations – a recommendation strongly supported by the author of this chapter. This recommendation is also applicable to the rest of the African continent. The setting of such locally based standards should consider the interactive, additive and potentiation effects of these chemicals on ONIHL.

3.2.3. Physical factors

Within the workplace, employees are exposed to numerous stressors that contain a range of physical agents concurrently, with some having been documented to potentiate ONIHL. Physical stressors that are documented to be risk factors for ONIHL include lighting (illuminance), heat, vibration and cold (Golmohammadi & Darvishi 2019).

As far as lighting is concerned, combined effects of unfavourable lighting (illuminance) and noise, which are nonauditory in nature, have been reported. This is where poor lighting had a combined negative effect with noise exposure on workers' performance because of increased extrinsic cognitive load

(Amiri et al. 2015; Bhattacharya, Tripathi & Kashyap 1989, 1997; Golbabaei et al. 2014; Gorai et al. 2007; Hygge & Knez 2001; Liebl et al. 2012; Lin 2014; Mangipudy 2010). Essentially, research implies that combined exposure to unfavourable illumination and noise has negative effects on the cognitive performance (such as attention, concentration and working memory) of employees (Golmohammadi & Darvishi 2019), with females found to be more sensitive to the perception of both noise and lighting than males at high stimulation levels (Yang & Moon 2018).

As far as heat is concerned, heat stress has been documented as an environmental factor that has the potential to aggravate noise-induced health effects, with heat stress enhancing noise-induced temporary threshold shift (Chen et al. 2007; Singh et al. 2010). Evidence on the auditory effects is, however, limited when compared with the nonauditory effects such as distress and fatigue, discomfort and hypertension (Golmohammadi & Darvishi 2019).

As far as vibration is concerned, vibration has both auditory and nonauditory health effects, with the nonauditory effects including physical and mental performance disturbances, loss of grip strength, anxiety, sleep disorders, concentration difficulties, fatigue, depression, irritability, shock and blanching (white finger) (Golmohammadi & Darvishi 2019). Several studies have documented the combined effects of vibration and noise, with vibration considered as a possible risk factor for developing ONIHL (Iki et al. 1989; Ljungberg, Neely & Lundström 2004; Miyakita, Miura & Futatsuka 1990; Nassiri et al. 2014; Sakakibara et al. 1989). In these studies, evidence indicates greater temporary hearing loss where vibration is present than where there is exposure to noise alone. Furthermore, it indicates higher low and high-frequency hearing loss in the presence of vibration, essentially proving the synergistic negative influence of combined exposure to vibration and noise (Iki et al. 1989; Pettersson 2013; Pyykkö et al. 2007; Sisto et al. 2017; Turcot et al. 2015; Zhu, Sakakibara & Yamada 1997).

As far as the effect of cold on ONIHL is involved, minimal research findings exist. Burström et al. (2010) and Horvath and Bedi (1990) reported on the combined health outcomes of concurrent exposure to noise and low temperatures. This is while Chao et al. (2013) investigated the combined influence of vibration, noise and low temperatures on the physiological parameters of 23 young healthy employees. Chao et al.'s (2013) study showed that this combination might cause white finger syndrome and permanent threshold shift. Golmohammadi and Darvishi (2019) contended that more investigations are merited on the combined effects of occupational noise exposure and low temperatures.

The physical stressors reviewed in this chapter (lighting, heat, vibration and cold) cannot easily be avoided in mining, nor can they be completely eliminated. However, careful understanding of their impact on occupational health conditions such as ONIHL requires attention from the African mining industry. This, with the goal of ensuring that HCPs consider these stressors, leads to a comprehensive preventive approach that is effective within the African context.

3.2.4. Occupational factors

Over and above the obvious exposure to excessive noise and nonutilisation of hearing protection, workload and shift work have been reported to present both auditory and nonauditory effects on the affected employee. Nonauditory effects in the form of physical and mental workload include heightened irritability, memory loss, tiredness, diminished performance and impaired cognitive performance (Golmohammadi & Darvishi 2019). As far as the auditory effects are concerned, Chen et al. (2007) reported on findings indicating that workload enhances noise-induced temporary threshold shift in healthy young subjects.

Golmohammadi and Darvishi (2019) reported that shift work is possibly a risk factor for noise-induced health outcomes that can be auditory or nonauditory in nature. Nonauditory effects that include noise-induced insomnia, gastrointestinal effects, coronary heart disease, fatigue and reduced cognitive function have been documented to be linked to night work (Attarchi et al. 2011; Jensen et al. 2016; Saremi et al. 2008). In a cross-sectional study, Chou, Lai and Kuo (2009) discovered that hearing loss in shift workers with a 12-h work schedule was substantially lower compared to shift workers with an 8-h work schedule, suggesting that shift workers are more susceptible to hearing loss than non–shift workers. However, there remains limited evidence in this area. Within the African mining industry, these risk factors have been well documented; however, increased efforts towards strategic implementation of preventive measures within HCPs are still required.

3.3. Conclusion

The ONIHL is complex, occurs in complex environments and is caused and exacerbated by a multitude of risk factors. For efficient preventive programmes, careful recognition and acknowledgement of all risk factors are paramount as they allow for true primary prevention to occur – before the standard HCPs are even adopted and implemented. Using South Africa as a case study, the quadruple influence on the risk presented in this chapter requires contextualisation within the African mining context. In the mining industry, employees are exposed to numerous stressors that comprise an assortment of personal factors, physical factors, chemical agents and occupational factors concurrently. Employees' exposure to one or a combination of these risk factors leads to poorer outcomes as far as occurrence of ONIHL and the success or failure of HCPs within the African mining industry.

Evidence on the influence of interaction and or combination of risk factors with noise exposure highlights the complexity of this area of practice. Evidence further raises the urgent need for locally relevant and responsive research to enable the development of appropriate and efficient preventive programmes for this context. Discounting risk factors to ONIHL by African mines minimises the effects that combined exposure has in exacerbating ONIHL, which may explain the current failure of the African mining industry to reduce and or eliminate ONIHL. Evidence indicating that the combined effects may have synergistic, additive, potentiation or antagonistic effects requires careful consideration in planning, implementing and monitoring HCPs within this context – bearing in mind the prevalence and/or incidence of the reviewed risk factors within the African mining industry.

Recognising and acknowledging all risk factors must occur in the context of the current significant risk to mining, coronavirus disease 2019 (COVID-19), where a paucity of data exists on its possible influence on hearing function. For example, the Head of Health at Minerals Council South Africa, Dr. Thuthula Balfour, is quoted as having conveyed that the cost of the vaccination programme against COVID-19 to the South African mining industry would be approximately US$20m (R300m), with the industry estimating that it would be able to conduct around 60 000 vaccinations per day, with potential to raise this daily number to 80 000. This Minerals Council's response to assist with the South African government's vaccination rollout of COVID-19 vaccines to their employees and mining communities as the country fights an increase in infections, with new variants discovered, is an important health and safety measure in South Africa. This is particularly important for South Africa because with more than 1.4 million positive cases and over 42 000 deaths by the end of January 2021, this country has the most numbers of COVID-19 infections and deaths on the African continent (Heiberg & Reid 2021).

The African mining industry would do well in investing in research into risk factors that still require solid evidence within the African context. Risk factors such as genetic factors as well as contextual diseases and their treatments and their influences on ONIHL, the impact of chemical agents that are most prevalent within the African mining context and the physical factors such as heat, vibration and cold all need investigation. A scoping review of the current African evidence, although mostly from South Africa, appears to indicate a concentration on the occupational risk factors such as the use of hearing protection and excessive noise exposure, as part of the pillars of HCPs' hierarchy of control. Such evidence will not only allow for the implementation of contextually relevant HCPs guided by informed policies but facilitate proactive primary preventive programmes implementation where, in addition to the HCPs, preventive programmes against each of the risk factors that aggravate ONIHL can also be implemented in African mines as part of employee wellness programmes that are already in place. Moroe's (2020) recommendation of viewing HCPs as CIs, where she argued that the success of these programmes within the African mining context depends on realist reviews such as contextually evidence-based evaluations, should be adopted. This approach will provide the mining industry and policymakers with contextual evidence for why some programmes work or do not work in some locations – with careful consideration of risk factors for ONIHL within the African context.

Section B

Approaches to HCPs in the context of low- and middle-income countries

Chapter 4

Hearing conservation programmes implementation in African mining contexts: Occupational audiology in action

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4.1. Introduction

Hearing conservation programmes are methods of interventions directed towards the reduction or potential elimination of work-related noise exceeding legislated limits in the workplace. These interventions aim to prevent ONIHL. Within the South African context, HCPs were formally introduced over two decades ago (Franz & Phillips 2001). Since then, various strategies have been implemented to address the iniquity of excessive exposure to noise in the work environment and its impact on the hearing function of workers. This chapter explores HCPs within the South African mining context, focusing on occupational audiometry to highlight factors surrounding screening versus diagnostic audiometry, including contextual practices and challenges relating to these activities. This chapter also offers solutions and recommendations for occupational audiology in HCPs in the context of South African mining specifically.

4.1.1. The history of occupational noise-induced hearing loss

The history of ONIHL is reported to date as far back as 1886 when Thomas Barr, a British physician, uncovered the first scientific association relating hearing loss and exposure to noise in boilermakers in Glasgow (Azizi 2010; Nair 2014). Four years after that, in 1890, knowledge regarding the pathophysiology of ONIHL was contributed to the science pool by Haberman (Azizi 2010). Approximately five decades later, in 1939, the 4 kHz distinctive noise notch on the audiogram was described by Fowler, and this notch is now considered a hallmark of NIHL (Azizi 2010). Despite this earlier evidence, it was only in 1965 that ONIHL was recognised and documented as an industrial medical condition in the UK. This led to the subsequent eligibility of workers for compensation under the National Insurance Act (Nair 2014). Since then, ONIHL has gained prominence globally as more and more cases of hearing loss were reported in industries prone to excessive noise, such as mining, aviation, the military, construction, transportation and farming (Chen, Su & Chen 2020; Girard et al. 2015; Khoza-Shangase, Moroe & Edwards 2020; Moroe et al. 2018; Nandi & Dhatrak 2008; Nelson et al. 2005; Ntlhakana, Nelson & Khoza-Shangase 2020a; Ranga et al. 2014; Sliwinska-Kowalska 2020; Sliwinska-Kowalska & Davis 2012; Zhou et al. 2020).

Arguably, ONIHL is prevalent globally, and millions of workers around the world are affected by it (Kurmis & Apps 2007; Le et al. 2017; Nelson et al. 2005; Sam et al. 2017). Even HICs, such as the USA (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. 2009) and Australia (Australian Safety and

Compensation Council 2006; Safe Work Australia 2010; Yamashita et al. 2005), still report significant cases of ONIHL. Although reports of ONIHL cases still exist in HICs, evidence suggests that the incidence is decreasing or at least stabilising in these parts of the globe (Nelson et al. 2005; WHO 2020). This is attributed to technological advances that have translated to most HICs increasingly investing in quieter equipment and machinery, as well as mechanising some processes in excessive noise–prone industries (Morata & Meinke 2016; Safe Work Australia 2010).

4.1.2. Hearing conservation programmes: The South African perspective

'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). Within this context, the South African mining sector is one of the significant, supportive pillars of South Africa's economic and political growth. Economically, mining was reported to contribute an astounding R286bn towards South Africa's GDP, with it being a major employer that was creating 4.5 million jobs and contributing R10 billion annually to the fiscal basket through pay-as-you-earn (PAYE) (Teke 2017). Key to its value within the South African society is that the mining industry is, by value, also the main contributor to black economic empowerment in the South African market, with most of the mining employees comprising black South African males (Worldwide Recruitment Solutions 2014).

Politically and historically, the mining sector has been accused of neglecting the basic rights of most mineworkers. Consequently, the mining industry in South Africa has been severely condemned for its inadequate health and safety conditions and its documented high fatality incident rates (Coulson 2018; Cullinan 2018; Nkosi, Claassen & Voyi 2015; Teke 2017). Occupational noise-induced hearing loss is an occupational health threat and remains a widespread hazard in the South African mining industry (Edwards et al. 2011; Kanji, Khoza-Shangase & Ntlhakana 2019; Khoza-Shangase et al. 2020; Moroe et al. 2018; Ntlhakana, Kanji & Khoza-Shangase 2015; Ntlhakana, Khoza-Shangase & Nelson 2020b; Strauss et al. 2012; Van Coller 2015).

Within the South African mining industry context, the described high prevalence of ONIHL has been attributed to excessive noise exposure where approximately 73% of the workforce is reportedly exposed to excessive noise (Edwards & Kritzinger 2012). Like other occupational challenges reported in most LMICs, this is a challenge. Some of these challenges include raised unemployment rates, economic and political instability, a heightened burden of tuberculosis (TB), HIV and AIDS (Gray & Vawda 2016; Khoza-Shangase 2021; Leboea 2017; Lehohla 2017; Stuckler et al. 2011). HIV, AIDS and TB are highly prevalent within the South African mining sector (Brits et al. 2012;

Khoza-Shangase 2020a, 2020b; Stuckler et al. 2011, 2013), and they have been found to exacerbate the impact of ONIHL (Brits et al. 2012; Khoza-Shangase 2020a, 2020b).

Over and above these recorded challenges, neglecting ONIHL, which, arguably, is not life-threatening, has negative health and safety effects that lead to negative economic sequelae such as poor job prospects and early retirement (Pelders & Nelson 2019). This, consequently, increases South Africa's economic burden where already high levels of unemployment exist (Leboea 2017). It is therefore worrying that regardless of the acknowledged significant fiscal contribution of South African mining, this sector remains one of the highly injurious to its workforce, including ear-and-hearing injuries. Consequently, the constant presence of ONIHL in this context merits careful deliberation and research with the aim of identifying efficacious, practical and contextual evidence-based strategies to eliminate excessive noise in such contexts, as determined by the country's MHSC (2014a, 2014b, 2015).

Almost two decades ago, in 2003, an agreement was signed by representatives of the mining industry with the South African MHSC. These representatives included government, labour the employer. This agreement specified two critical milestones as targets to be achieved towards tackling ONIHL in South African mines (Moroe et al. 2019; Phillips, Heyns & Nelson 2007; Strauss et al. 2012). The two milestones were (1) eradication of hearing worsening of more than 10% by December 2008 in excessive occupational noise-exposed workers and (2) reduction of total noise produced by any equipment in the workplace, so that by December 2013, it would not surpass 110 dBA at any singular instant. These two milestones were later re-examined and then amended just over 10 years later, in 2014, following the realisation that they had not been met (Dekker et al. 2011; Edwards et al. 2011; Edwards & Kritzinger 2012). The newly revised milestones, reflected in Table 4.1, are recorded as follows: (1) 'total operational or process noise emitted by any equipment must not exceed a milestone sound pressure level of 107 dB (A) by

TABLE 4.1: Towards prevention of ONIHL milestone reviews (2003–2014).

Milestone	Description	Overview
2003	No deterioration in hearing greater than 10% among occupationally exposed individuals.	December 2008
	Total noise emitted by all equipment installed in any workplace must not exceed a sound pressure level of 110 dB(A).	December 2013
2014	No individual employee's STS should exceed 10 dB from the baseline in both ears.	December 2016
	No individual employee's STS should exceed 25 dB from the baseline in both ears.	December 2024
	The total operational or process noise emitted by any equipment used in the mines must not exceed 107 dB(A).	December 2024

Key: STS, standard threshold shift.
Source: MHSC (2014a, 2014b).

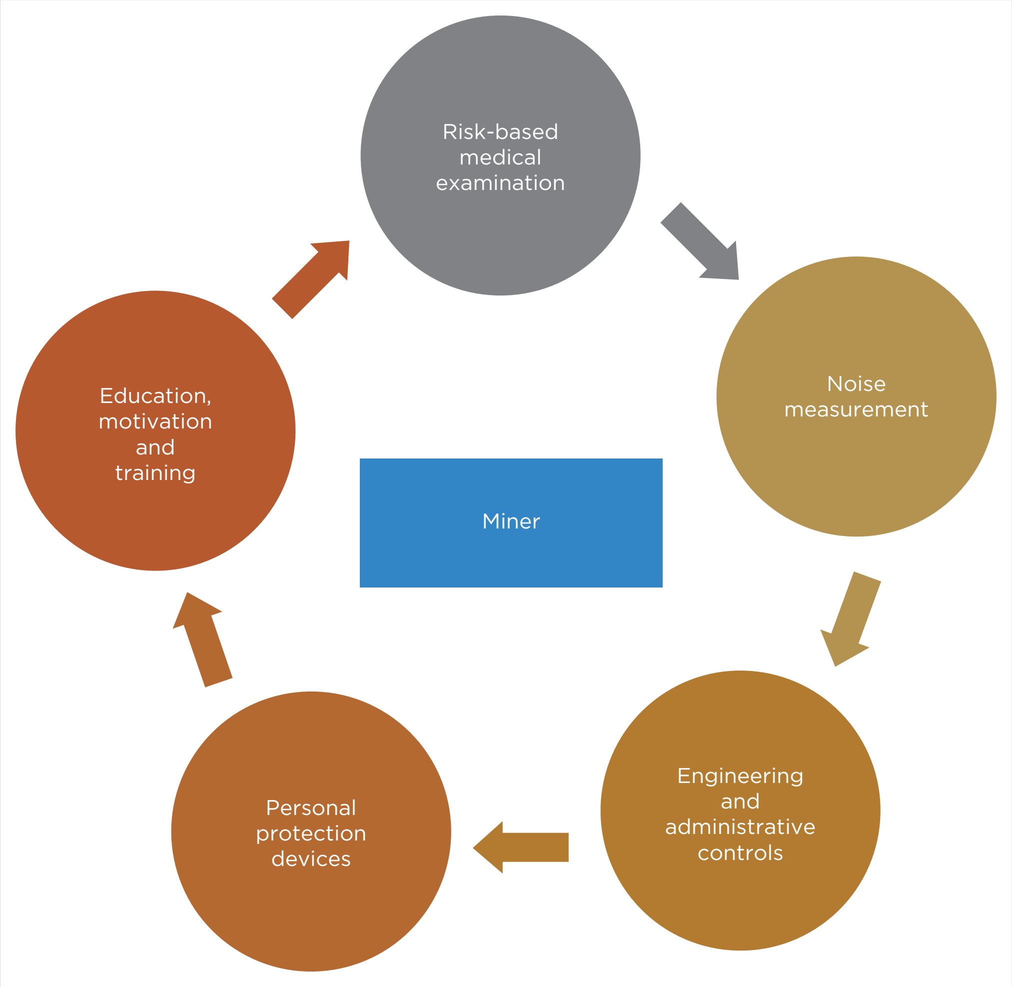
December 2024, and (2) no employee's STS will exceed 25 dB from the baseline when averaged at 2 000 Hz, 3 000 Hz and 4 000 Hz in one or both ears by December 2016' (MHSC 2014a, 2014b, 2015).

4.1.2.1. Factors contributing to poor success in achieving the MHSC milestones

Moroe (2018) explored ONIHL in large-scale mines in South Africa, from the formulation of policy to HCPs' implementation and their monitoring. Findings revealed that the main contributing factor to the South African mining industry not meeting proposed targets was the MHSC's failure to clearly define and institute the summit action strategies before milestone implementation. Another contributing factor that Moroe (2018) found was the lack of mining sector collaborative stakeholder engagement and the exclusion of audiologists in the formulation of the 2003 milestones. This author argued that the collaborative cooperation of all stakeholders, with audiologists playing a central role, is key towards addressing ONIHL within a CIs paradigm (Moroe 2020). This position is consistent with the acknowledgement made by the South African mining industry following the failure to meet the 2003 MHSC milestones, where they stated that 'they are not making the desired progress with NIHL, which is a major occupational health concern' (Booyens 2013, p. 1). They further added 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'. Nonetheless, the mining industry itself is consigned to 'the massive reduction and elimination of occupational noise-induced hearing loss' (Booyens 2013). These are important factors to consider in planning, implementing, reviewing and monitoring OHS objectives within South African mining. These lessons from the South African context are valuable for the rest of the continent to take heed of in their setting and or reviewing of their milestones within the African mining context.

4.1.3. HCPs actionalised within occupational health and safety milestones

For HCPs to be successful, they need to speak to the overall OHS milestones (MHSC 2014a). As part of OHS, HCPs, comprising pillars of the hierarchy of control, as illustrated in Figure 4.1, are implemented. The interaction of the HCP pillars and set milestones that were promulgated in 2003 and subsequently revised in 2014 is depicted in Figure 4.1. Scrutiny of these milestones indicates that, superficially, these milestones may seem to be focusing on two pillars of HCPs – engineering control and surveillance audiometry. However, closer inspection reveals that these milestones encompass all the pillars of HCPs,



Source: Adapted from Ntlhakana et al. (2020b).

FIGURE 4.1: Interaction of hearing conservation programme pillars and milestones.

which is in line with good practice and the hierarchy of control as recommended (Edwards & Kritzinger 2012). To demonstrate this, for example, the first objective (controlling noise at source) is concerned with monitoring periodic noise exposure, engineering and administrative controls, as well as record-keeping. The second objective (eliminating personal exposure to individuals) focuses on administrative controls, audiometric surveillance, education and training, use of PPE and record-keeping.

As earlier highlighted, the inclusion of all pillars in the implementation of HCPs is critical to their success and sustainability. Moroe (2018) interrogated why then, if all the pillars of HCPs were implemented as recommended, the

2003 milestones were revised. This author offered a fourfold answer to this question:

1. The noise emitted by the equipment was capped at 110 dB. According to the regulatory bodies, the maximum permissible noise is 85 dB(A) for an 8-h day shift. Therefore, 110 is excessively loud and is beyond the legislated maximum. In fact, according to the NIOSH (2020), the permissible duration in a place with 110 dB(A) is below 2 min.
2. Where noise exceeds 85 dB, workers should be provided with hearing protection devices (HPDs) (Suter 2012). During the modelling of a feedback-based noise management matrix to predict hearing loss patterns in people exposed to excessive noise, Moroe et al. (2020) found that HPDs, including custom-made devices, did not offer sufficient protection, as the attenuation these devices provided ranged from the highest attenuation of 18.35 dB(A) to the lowest attenuation of 7.1 dB(A). Therefore, employees exposed to 110 dB(A) noise levels, despite wearing their HPDs, would still be exposed to excessive noise in the workplace – noise above the legislated level of 85 dB.
3. Audiometric surveillance, which is a critical tool in identifying early cases of ONIHL, was implemented for *compensation purposes* rather than *preventive purposes*, as it was concerned with the PLH. In essence, audiometric surveillance was used as a tool to establish the damage or hearing loss for compensation purposes, instead of having primary prevention as a goal.
4. Lastly, prevailing contextual challenges such as the lack of sufficient appropriately qualified personnel in this area, exclusion of some key and relevant stakeholders such as audiologists and mineworkers, the arguably nonconducive political climate and organisational culture may also have contributed to the partial achievement of the set targets.
5. Scrutiny of the 2014 revised milestones indicates that these challenges were carefully considered, hence the different outcomes recorded.

The 2014 revised milestones operationalised the same objectives as the 2003 milestones; however, the outcomes were different. The first objective – controlling noise at the source – saw a 3 dB(A) reduction from 110 dB(A) to 107 dB(A). This 3 dB(A) reduction, while it is still above the 85 dB(A) legislated maximum, significantly decreases the impact of excessive noise exposure on the individual. This is because the human ear can distinguish the significant multiplying of the energy of sound. Therefore, when sound is doubled, the ear perceives it as a rise of 3 dB based on the logarithmic scales (Pulsar Instrument 2020). In individuals exposed to excessive noise, a small increase in the number of decibels can cause significant damage to the individual's hearing. Inversely, a decrease of 3 dB can halve the sound of energy and thereby significantly decrease the impact of noise exposure on the individual (Pulsar Instrument 2020). Therefore, in the current revised milestones, reducing the noise level from 110 dB(A) to 107 dB(A) halved the impact that would have been caused by exposure to 110 dB(A). As alluded to earlier, this is still above the legislated permissible maximum. Additionally, the concerns regarding the use of HPDs in noisy environments still apply in this case.

A significant and positive change to the second objective in the revised milestones, eliminating personal exposure, is that of moving from the use of PLH, which is typically used to calculate the compensation pay-out, to the use of STS, as a primary hearing loss preventive measure. Ntlhakana et al. (2020a) illustrated the importance and value of utilising STS for positive preventive audiology outcomes when applying PDMS that are currently being implemented in South African mines. To further illustrate the significance of shifting from the PLH to the STS, the next section of this chapter focuses on the importance of audiometric surveillance in preventing hearing loss and in determining compensation for ONIHL.

4.1.4. Audiometric surveillance in occupational settings

Audiometry in occupational settings is a well-established component of occupational health surveillance for workers exposed to noise exceeding the legislated noise levels (MacLurg, McCaughan & McQuillan 2004). According to the *Occupational Health and Safety Act of 1993* (OHSA), audiometry should be conducted by a 'competent person'. The Act defines 'competent person' as (Oosthuizen 2006):

> [*A*] person registered in terms of the *Health Professions Act of 1974,* with the HPCSA in any of the three categories – a) i) ear, nose and throat specialist (otorhinolaryngologists); ii) Speech Therapist and Audiologist; or iii) Occupational Medicine Practitioners; or b) 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 58 of 1995), and registered with the South African Society for Occupational Health Nursing (SASOHN). (n.p.)

Moroe and Khoza-Shangase's study within the South African mining sector (2018) explored the role of audiologists in the management of ONIHL. Findings from this study revealed the noticeable absence of audiologists within the mining context and their exclusion in important decision-making regarding the formulation, implementation and evaluation of HCPs. This is concerning as audiologists are professionals, whose scope of practice primarily focuses on hearing loss prevention, identification and diagnosis. The delegation of this role to audiometrists as specified in the OHSA (Oosthuizen 2006), is also concerning as audiometrists are not trained on hearing loss and its prevention, identification and diagnosis. Granted, audiometrists do not diagnose hearing loss; however, their seeming independent involvement in audiometry surveillance is concerning, and solid plans as part of regulated task-shifting should be implemented where these cadres are supervised by a competent person in their primary preventive role.

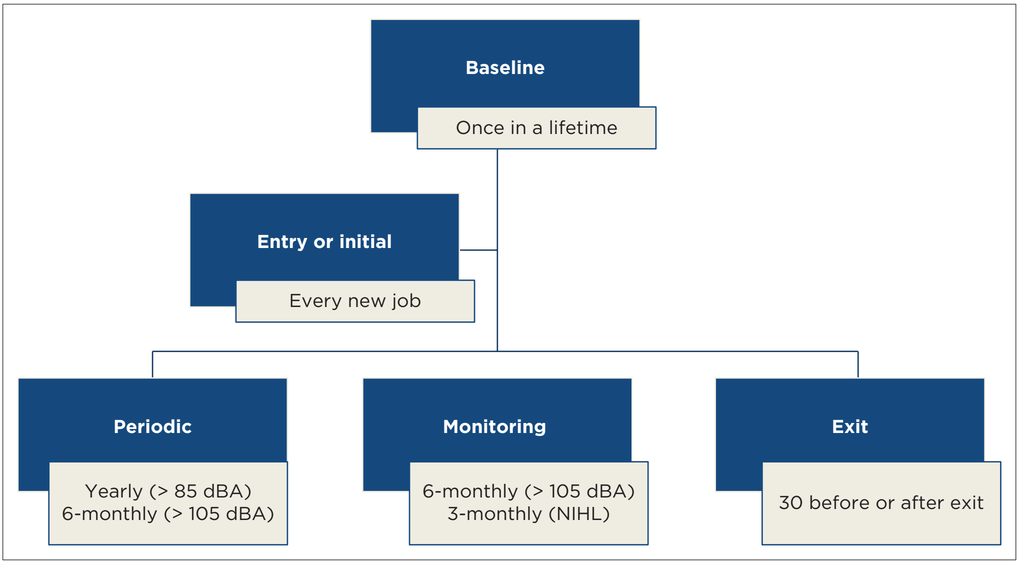
Audiometry within occupational audiology serves a twofold purpose: (1) early identification of the need for intervention of hearing loss and (2) establishing the degree of impairment for compensation purposes. Drawing from the OHS milestones presented earlier, as far as minimising noise exposure to the individual is concerned, audiometry was the key feature to establishing the desired outcomes. Looking at the 2003 milestones, the focus was on the latter part – calculating the degree of impairment for compensation purposes. This is in contravention of the primary application of audiometry – hearing loss prevention and its early detection. Fortunately, this contravention was amended in 2014 where the revised current milestones are concerned with prevention and early detection of hearing loss through the adoption of the use of STS.

In reference to the HPCSA, to determine compensation for hearing loss because of excessive noise exposure, competent persons must refer to Circular Instruction No. 171. Two compensation systems (with different assurance or insurance schemes or providers) are located under Instruction 171, namely, the *Occupational Diseases in Mines and Works Act* (ODMWA) and the *Compensation for Occupational Injuries and Diseases Act of 1993* (COIDA). Instruction 171, issued in 2001, is located within the COIDA (1993). Different assurance companies manage the claim for compensation process, for example, the original source, Rand Mutual Assurance Company Limited, usually does so on behalf of the mines, while the Federated Employers Mutual Assurance Company (RF) (Pty) Ltd does so for the construction industry. In Instruction 171, audiometric measures within a screening and diagnostic context constitute the basis for compensation eligibility, claim submission and compensation pay-outs (Department of Labour 2001). For ease of reference in this chapter, we will refer to audiometry concerned with the prevention and early detection as screening audiometry, and that for calculating the degree of impairment will be referred to as diagnostic audiometry.

Figure 4.2. reflects the screening audiometry and criteria as defined by Instruction 171 and how prevention and compensation are inextricably linked (Department of Labour 2001).

According to Instruction 171 (Department of Labour 2001), used by both the mining and construction industries, there are four audiograms for hearing conservation and compensation for hearing loss:

1. Baseline audiogram:
    - Referred to as the reference point for occupational history, it is the first audiogram obtained from the audiometric examination conducted before employment or within 30 days after employment has commenced.
    - It is conducted after a period of a minimum of 16 h has lapsed after employee noise exposure.
    - HPD usage to affect this attenuation in noise exposure is not deemed to be acceptable (*Mine Health and Safety Act of 1996* [MHSA]*)*.



Source: Adapted from Franz and Phillips (2001, pp. 195–232).

FIGURE 4.2: Screening audiometry types and criteria for HCP and compensation.

- Two audiograms should be obtained on the same day under similar conditions to maintain the validity of the results. The audiogram with the smallest PLH is the one that is recorded.
- All audiograms that follow are to be compared with this baseline audiogram to determine PLH deterioration.
- Exclusions are made for workers with outer and middle ear pathology, for example, impacted cerumen, otitis externa and otitis media. These conditions should be managed before testing.
- If the audiometrist is unable to obtain a valid baseline audiogram (i.e. differences of 10 dB or more across the test frequency range), a referral for diagnostic audiology is recommended.

2. Follow-up screening audiogram(s):
    - An audiogram(s) is conducted as part of the continuous audiometric medical surveillance process.
    - It is conducted after a period of a minimum of 16 h has lapsed after employee noise exposure.
    - Suitable HPD usage may be applied to meet the minimum 16-h noise-free prerequisite.
3. Types of audiograms and objectives:
    - An *entry audiogram* is obtained on an employee who has moved from company A to company B or an employee who has moved to a different section within company A.

   - A *periodic audiogram* is obtained annually for the early identification of hearing loss.
   - A *monitoring audiogram* is obtained from employees who are more at risk of developing ONIHL, for example, those who exposed to noise levels > 105 dBA and early diagnosis of NIHL (DMRE Circular 2012).
   - The employer is responsible for ensuring that a *periodic (screening) audiogram* is conducted at least once a year for employees who require medical surveillance (i.e. workers exposed to an equivalent noise level [Neq] exceeding 85 dB[A]): 12-monthly if noise levels ≥ 85 dB(A); 6-monthly if noise levels ≥ 105 dB.
   - An *exit audiogram* is to be performed on employees who require medical surveillance when said employee is transferred permanently to a workplace not requiring surveillance. An audiogram that has been obtained within 6 months preceding the employees exit may be utilised as the exit audiogram, provided there has been no incident that may have impacted the employees hearing ability since that last audiogram within those 6 months.
   - An HPCSA registered audiologist is to perform the *diagnostic audiogram*. It is conducted after a period of a minimum of 24 noise-free hours has lapsed after employee noise exposure. HPD usage to affect this attenuation in noise exposure is not deemed to be acceptable to fulfil this noise-free criterion. When the screening audiogram reflects a ≥ 10% average binaural deterioration in hearing from the initial PLH, referral for a diagnostic audiogram must be made. Two consistent (re: results) audiograms are required where the 5 specified frequencies (inclusive of 3 kHz) are emphasised. These five frequencies (500 Hz, 1 kHz, 2 kHz, 3 kHz and 4 kHz) are used to calculate an average binaural loss ≥ 10% PLH.

4. Compensation:
   - This diagnosis of an NIHL has legal implications for both the employer and the employee. Therefore, audiologists play a critical role in diagnosing hearing loss in occupational settings, as their diagnostic audiological findings and recommendations determine the outcomes for both the employer and the employee.
   - Compensation would thus be the employer's liability as paid via the Compensation Commissioner who would assume liability or through the employer's mutual association. Compensation for workers will only occur for a defined fixed deterioration amount (PLH shift ≥ 10%) denoted as the PLH.
   - Approved frequency-specific tables provided as part of Instruction 171 are used to calculate the PLH, where the sum of the hearing losses at 500 Hz, 1 000 Hz, 2 000 Hz, 3 000 Hz and 4 000 Hz is calculated from a specific audiogram.

- Permanent disablement (PD) calculation: The first PLH is computed from the better of the two first screening baseline audiograms conducted on the same day. The employee is only compensated if a deterioration by 10% or more from initial baseline PLH is found. The hearing threshold levels (HTL) from the better of the two diagnostic audiograms are used. In the absence of a baseline PLH, the PLH from the diagnostic audiogram is regarded as the value from which PD is computed. PD is calculated by dividing the value of the PLH into two; 100% hearing impairment is thus equal to 50% PD.
- Compensation eligibility and submission: To qualify for a claim, the employee's noise exposure must exceed 85 dB (A) during the course of their workday. For employees whose noise exposure must result in a ≥10% PLH deterioration from the baseline audiogram. For employees whose noise exposure has resulted in ≥10% PLH and for whom no baseline is available.
- Compensation review will be deliberated as discussed or on exit examination.
- It is largely accepted that as soon as the employee is withdrawn from noise, further hearing deterioration does not occur. After removal from occupational noise (e.g. redeployment, retrenchment and retirement), the claim is required to be registered within a 12-month period.

Chapter 5 delves into the different classifications of audiograms, as well as the complexities surrounding these in the prevention of ONIHL, which are valuable for the current discussion.

Kew (2018) highlighted the importance of limiting audiograms to those experiencing noise exposure. Therefore, workers who are not exposed to noise, such as those who may be based in offices far away from noise, may not necessarily need to have their hearing tested as frequently as those exposed to noise. This may also assist in channelling the resources to where they are most needed.

4.2. Recommendations for audiometry within HCPs

There is no denying the importance of audiometry in the identification and diagnosis of ONIHL and the resultant outcomes. This value has implications for having a competent person conducting and interpreting the audiogram, as the diagnosis determines the outcomes for both the employer and the employee. The absence of audiologists in the African mining sector presents challenges for accurate diagnosis of hearing loss. The understanding of the different audiograms and the procedures and protocols involved in each are critical in ensuring that the interpretation of the audiogram is accurate. Furthermore, understanding the differences between the PLH and the STS is fundamental in the interpretation of the audiogram as, while they are both fundamentally capable of identifying a shift in hearing, thereby ensuring early detection, the PLH approach does not explicitly mandate monitoring the employees at risk. Therefore, individuals conducting audiometry surveillance need to be aware of these subtle differences in approaches and procedures as the diagnosis has implications for both the employer and the employee. As such, Kew (2018) suggested a few considerations for audiometry in action, and these include the following:

1. Percentage loss of hearing misses early NIHL and HCPs that use PLH cut-offs as triggers for action will miss NIHL until it is moderate to severe in degree.
2. The best mechanisms for identifying early NIHL remain with the interpretation of the audiometric results by a trained professional as recommended by the OHSA.
3. An audiologist usually performs the most detailed and comprehensive audiogram, which may be supplemented by other helpful tests such as otoacoustic emissions. Under normal circumstances, such testing may not be practical or required for audiometry surveillance, but it may be useful to aid in diagnosis.
4. At present, there is no nationally agreed-upon cut-off for what constitutes reportable NIHL in reference to OHS.
5. The purpose of surveillance audiometry is not to diagnose but rather to identify workers exposed to excessive noise to enable requisite action; this action may include referral for diagnostic hearing testing.

■ 4.3. Conclusion

This chapter has highlighted the importance of audiometric surveillance in occupational settings, with contextual relevance to the mining sector within the African context. Audiometry plays a critical role in preventing and ultimately diagnosing hearing impairment in those exposed to excessive noise in the work environment. This has implications for practitioners who are involved and trusted to conduct audiometry. A solid understanding of the different audiograms and approaches utilised – PLH versus the STS – is fundamental in the accurate diagnosis of ONIHL, as this has significant implications for both the employer and the employee. The steps leading to compensation are also critical, as a misdiagnosis or misinterpretation may have catastrophic consequences for both the employer and the employee. Therefore, sound knowledge and understanding of audiograms in relation to audiometry surveillance is fundamental in occupational audiology.

Chapter 5

Complexities and challenges of different classifications of audiograms in the prevention of occupational noise-induced hearing loss

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5.1. Introduction

An audiogram is a universally accepted standard of recording hearing sensitivity despite differences in patient-related historical data, types of tests conducted and test environments which may differ from place to place

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(Jerger 2013; Veith 2021; Vogel et al. 2007). Therefore, solid knowledge and understanding of the audiogram is fundamental to making sound clinical diagnoses and recommending the best management plan for patients with a hearing impairment. This is particularly important in occupational audiology, where the audiogram is also key in quantifying NIHL for compensation purposes. Therefore, this chapter deliberates on the use of the audiogram in HCPs, commencing with a brief history and the development of the audiogram, with the traditional classification of hearing loss as depicted by the audiogram. This is then followed by a discussion of the audiogram in the prevention of and compensation for ONIHL. The use of the audiogram for the purpose of compensation, with a focus on the PLH and the STS as metrics for calculating hearing loss for compensation purposes, is also presented. An African context case study from Tanzania on the use of the UK Health and Safety Executive (UKHSE) scheme for the categorisation of audiograms is presented as an example of the use of a different audiogram classification system in HCPs. Lastly, the chapter highlights considerations for practitioners in the diagnosis of NIHL.

An audiogram can be best defined as the visual representation or output of a standard audiometric examination which captures the patient's hearing thresholds along the frequency spectrum on an inverted graph (Charih et al. 2020). Vogel et al. (2007) describe the audiogram as the banner of clinical audiologists' work since it gained recognition after World War II. This period (after World War II) showcased audiology as a profession because most innovations such as HCPs emerged during this era (Vogel et al. 2007). Vogel et al. (2007) lament how without the data contained in the audiogram, physicians could not properly document pathological conditions of the ear nor prepare for otologic surgeries. These authors therefore argue that this information has implications for occupational audiologists who may need to quantify hearing loss for preventive, compensatory and rehabilitative interventions in people exposed to excessive noise in the workplace.

5.1.1. History of the audiogram

The audiogram was developed as far back as the 1940s, during World War II, documented as the early days of audiology as a discipline (Manchaiah 2011). Since then, the audiogram has become the typical graphical depiction of the results of pure-tone audiometry (Manchaiah 2011), with audiometry being broadly defined as the measurement of hearing sensitivity (National Health and Nutrition Examination Survey 2003). According to Hedge (1987), as cited by Vogel et al. (2007, p. 82) 'the audiogram was born out of necessity as the signature tool specific to the hearing scientist's ability to observe, measure, and record hearing behaviour'. In the absence of an audiogram, the recording of the test results would be unsystematic (Vogel et al. 2007). As audiology developed into a profession, the audiogram showcased technological advances and became routinely used in the clinical audiology environment (Vogel et al. 2007).

Before the term audiogram was coined, the standard for recording hearing sensitivity (SRHS) tool was used to document hearing acuity. Initially, the SRHS was in the form of an 'Auditory Chart' invented by Arthur Hartmann in 1885 to document tuning fork results (Zwislocki & Feldman 1970). This chart included the left and right ear tuning fork representation on the abscissa (the horizontal [x] axis) and percentage of hearing along the ordinate (vertical [y] axis) of a standard two-dimensional graph (Vogel et al. 2007). The Auditory Chart provided values that allowed for comparison between air and bone-conduction tuning forks, which has some similarity to the current audiogram (Staab 2014). However, the 'norms' used to interpret the results in the Auditory Chart were subjective and led to uncertainty, as the chart did not provide guidance about the hearing levels in relation to hearing sensitivity (Staab 2014). Despite these challenges with the Auditory Chart, the graphics plotted on it resembled a chart with numerical values representing norms for different frequencies for comparison purposes (Staab 2014).

As the years progressed and technology advanced, in 1903, Max Wien developed a 'Sensitivity Curve', or the audibility curve, using a telephone receiver. Using this sensitivity curve, physical sensitivity was plotted along the ordinate to depict the relationship between hearing threshold and frequency (Vogel et al. 2007; Zwislocki & Feldman 1970). This audibility curve had the sensitivity scale along the ordinate, which related to the commonly used different frequency tuning forks. This method presented fixed absolute intensity thresholds for frequencies between 50 kHz and 12 kHz, with the highest sensitivity near 2 200 Hz, which was 10^8 times that at 50 Hz (Staab 2014). According to Staab (2014), this was an error and was rectified by Wegel at the Bell Telephone Laboratories. Wegel plotted the auditory area, including the dynamic range (threshold of audibility and threshold of feeling) to show the absolute threshold to be well below 0.001 dyne C^{-2} at 220 Hz (Staab 2014). Staab (2014) argues that despite Max Wien's results being erroneous, the results of the exercise were clear for the maximum and minimum limits of audibility of pitch based on the intensities where the measurements are made. Wien's Sensitivity Curve was therefore the first graph to demonstrate the link between hearing thresholds (sensitivity) and frequency (Staab 2014).

In 1904, Politzer and colleagues proposed an alternative technique to record hearing sensitivity measurements and to provide a 'standard' for terminology. This technique was called the Acumetric Schema (Zwislocki & Feldman 1970). The Acumetric Schema was debated at the 7th International Congress of Otology in Bordeaux, France, but it was not adopted until the 8th International Congress of Otology in Budapest, Hungary the following year.

The Acumetric Schema attempted to standardise nomenclature for ‘auditory area’ and ‘auditory horizon’. Unfortunately, this method was never universally accepted (Vogel et al. 2007; Zwislocki & Feldman 1970).

It was only in 1922 that the term audiogram was first coined by Fletcher, Fowler and Wegel (Manchaiah 2011). The earlier SRHS tools, although resembling the current audiogram, did not provide quantitative values relative to normal hearing, and it was only in 1922 that Fletcher and colleagues first used frequency (pitch) at octave intervals mapped along the abscissa and intensity downward along the ordinate as a degree of hearing loss (Vogel et al. 2007). Since then, the audiogram has evolved and reflects the developments in audiometry from air and bone conduction in the 1920s and has become the backbone of evaluating any hearing loss (Levine 2003). It has also become the single most useful tool to depict hearing acuity in patients with a hearing loss (Hain 2007), including for patients exposed to excessive noise in the workplace. As such, solid knowledge, understanding and interpretation of the audiogram is the hallmark of diagnosing and recommending the best intervention for patients with a hearing loss (Charih et al. 2020). This is more so for occupational audiologists who prevent, monitor and manage ONIHL, because their interpretation of an audiogram has career and livelihood consequences for an individual diagnosed with this occupational health condition.

5.1.2. Audiogram classifications and occupational noise-induced hearing loss prevention and compensation

Three classifications are critical when examining an audiogram: (1) the configuration (shape of the curves), (2) symmetry (relationship between curves of both ears) and (3) and severity (location along the y-axis) (Miyakita & Miura 1986; Musiba 2020; v. d. Drift, Brocaar & v. Zanten 1988). These classifications reveal valuable information about the nature, potential causes and, ultimately, the diagnosis of a hearing impairment (Charih et al. 2020). This is important in diagnosing NIHL, as a configuration depicting a notch at 4 000 Hz, for example, is characteristic of ONIHL (Charih et al. 2020; Schlauch & Nelson 2014), while a gently sloping hearing loss across the high-frequency spectrum is suggestive of presbycusis (Charih et al. 2020; Schlauch & Nelson 2014).

The most appreciated application of an audiogram is its ability to visually classify the degree and types of hearing loss (Vogel et al. 2007). The earliest audiogram classification, developed by Guild in 1932 and Carhart in 1954, used configuration, severity and interaural asymmetry as part of its features (Margolis & Saly 2007). This classification was used to categorise tests and appreciate associations between audiogram characteristics and ear pathologies in relation to clinical populations (Margolis & Saly 2007). Since then, numerous attempts have been made to classify the degree of hearing loss by decibel values plotted on the audiogram (Manchaiah 2011). For instance, in 1981, Clark proposed a system where hearing loss was classified according to 'mild, moderate and severe' degrees for compensatory purposes in the USA after World War II (Manchaiah 2011). In 1986 Miyatika and Miura classified the audiogram to show the link between the severity in NIHL and subjective complaints in relation to daily life (Miyatika & Miura 1986). The audiogram was classified into normal or NIHL and was categorised into five stages (I, II, III, IV and V) (Miyatika & Miura 1986). Further details on these stages can be found in Miyatika and Miura (1986). Recently, Musiba (2020) proposed the use of the UKHSE scheme, where the audiogram is classified in a simple and unambiguous category, from acceptable hearing ability to rapid hearing loss monitoring and documenting. This UKHSE classification method will be discussed in detail later in this chapter.

In occupational audiology, specifically in the management of NIHL within HCPs, the audiogram is often utilised for compensation purposes as part of occupational health disease management. To this end, Musiba (2020) laments that most of the available classifications are geared towards compensation for hearing impairment and not towards prevention. This author posits that the UKHSE method is better as it is geared towards prevention, which should be the primary goal to avert the need for compensation (Khoza-Shangase, Moroe & Edwards 2020).

When classifying the hearing results on the audiograms, different guidelines for the definition of ONIHL exist (Lie et al. 2017), and these include features such as frequency specification, the audiometric notch, as well as prevention versus compensation audiogram measure.

☐ 5.1.2.1. Frequency specification as a classification for ONIHL

Prolonged exposure to intensive noise can result in hearing loss (Le et al 2017; Lie et al. 2015; Moore 2016). Typically, this loss is observable in the audiogram in frequencies close to 4 kHz, but the exact site of the lesion (affected frequencies) can vary from 3 kHz to 6 kHz (Moore 2016). With NIHL, there are several cases where the audiometric thresholds remain close to the age-expected values for frequencies up to 3 kHz, with elevations at 4 kHz and 6 kHz (Moore 2016). Moore (2016) argues that as such, in some countries, compensation for ONIHL is based on the mean estimated NIHL at 1 kHz, 2 kHz, 3 kHz (UK) or 0.5 kHz, 1 kHz, 2 kHz and 3 kHz (USA). In South Africa, compensation is based on the average estimated at 2 kHz, 3 kHz and 4 kHz (Edwards & Kritzinger 2012), while in Tanzania compensation is based on calculated average of 1 kHz, 2 kHz, 3 kHz, 4 kHz and 6 kHz (Musiba 2020). With these classifications, Moore (2016) raises concerns regarding individuals whose ONIHL is located at frequencies above 3 kHz as they are often not eligible for compensation. This author argues that using the mean ONIHL at 1 kHz, 2 kHz, 3 kHz or 0.5 kHz, 1 kHz, 2 kHz and 3 kHz is premised on the covert assumption that hearing loss for frequencies above 3 kHz has no significant negative effects. Arguably, the countries that classify hearing loss in the 0.5 kHz to 4 kHz range on the audiogram are concerned with spoken communication, as this frequency range is documented to be of greatest clinical relevance in terms of spoken communication (Lie et al. 2017). On the other hand, classifications that emphasise 3 kHz to 6 kHz range seem to focus on ONIHL, as this frequency range is recorded to be most susceptible to excessive noise exposure (Lie et al. 2017). In engaging these frequency ranges, in relation to the African, and more specifically the Tanzanian and South African regulations, it can be argued that both classifications of the audiogram are mutually inclusive and overlap in that the same audiogram serves as both the tool for preventing hearing loss by preserving the speech frequencies and compensation by focusing on the frequencies most susceptible to noise.

Moore (2016) describes the strong evidence of the adverse effects of NIHL in frequencies above 3 kHz. These include speech comprehension, sound localisation and discrimination, particularly in noisy backgrounds. This is an important consideration because compromised communication among workers leads to increased risks for accidents (Kirchner et al. 2012; Momm & Geiecker n.d.). Therefore, audiometric thresholds at 4 kHz and possibly at 6 kHz should be considered when determining compensation for ONIHL in medicolegal contexts (Moore 2016).

☐ 5.1.2.2. Audiometric notches as a classification for ONIHL

Typically, audiograms obtained from workers exposed to excessive noise have a notched configuration (Azizi 2010). Audiometric notches are defined as hearing loss at 3 kHz to 6 kHz compared with higher and lower frequencies (Lie et al. 2015). The audiometric notch was first described by Fowler in 1939, and it was considered a hallmark for NIHL (Azizi 2010); it is primarily used to diagnostically differentiate between noise-induced and ARHL and ototoxic hearing loss (Khoza-Shangase 2020; Lie et al. 2017; Majumder et al. 2018). Authors such as Le et al. (2017), Lie et al. (2015) and Rabinowitz (2012) concede that making a distinction between NIHL and age-induced hearing loss and ototoxic hearing loss is difficult. Majumder et al. (2018) support the association of age and deteriorating hearing thresholds; however, they also highlight that not all individuals experience decreases in hearing sensitivity with age. Moreover, although the notch distinguishes NIHL from ARHL and ototoxic hearing loss, the notch may diminish at 8 000 Hz in ARHL, therefore making it hard to differentiate between the two conditions (Le et al. 2017; Lie et al. 2015, 2017).

There is poor consensus regarding the exact nature of the audiometric notch (McBride & Williams 2001; Osei-Lah & Yeoh 2010). This lack of agreement is a result of the fact that clinically and historically, the notch was considered a strong indicator for NIHL (McBride & Williams 2001), yet there is evidence that NIHL may be observed in the absence of a notch (Kirchner et al. 2012; Lie et al. 2015), and it can also occur without a history of previous exposure to noise (Cameron & McBain 2019; Nondahl et al. 2009; Osei-Lah & Yeoh 2010).

To illustrate the poor consensus, Nondahl et al. (2009) draw from a study by McBride and Williams (2001), where three raters (otolaryngologist, audiometrist and occupational physician) reviewed 634 audiograms to assess the presence of a notch in the audiogram. The presence of the notch accompanied by a history of noise would confirm noise exposure in that person. Findings from this study revealed poor agreement between raters as raters respectively identified 26%, 49% and 68% of the audiograms as having an audiometric notch. Based on the interclass correlations between ratings, it was concluded that visual inspection of the audiogram is not an objective technique for identifying audiometric notches (Nondahl et al. 2009). As such, these authors recommend the use of algorithms to objectively define the presence of a notch. Nondahl et al. (2009) present the findings of their study, where they evaluated the use of algorithms to objectively define notches. The reader is referred to this article for further details as the algorithms are beyond the scope of the current chapter.

NIHL is typically bilateral in presentation, and by extension, the audiometric notch should be bilateral. However, Wilson and McArdle (2013) argue that unilateral audiometric notches are more frequently observed than bilateral ones. Because audiometric notches typically occur in people without a previous history of exposure to noise, this may exaggerate the incidence of ONIHL and potentially the implementation of HCPs unnecessarily (Lie et al. 2015). Lie et al. (2015) posit that the occurrence of an audiometric notch indicates the presence of NIHL while its absence makes the diagnosis of NIHL less probable. McBride and Williams (2001) also argue that the notch can be observed anywhere in the high-frequency range from 3 000 Hz to 6 000 Hz. Majumder (2018) claims that the notch at 4 kHz is a clinical sign of NIHL and may be instrumental in confirming the diagnosis, while the notch at 6 kHz is variable and must be interpreted cautiously for a NIHL diagnosis. Furthermore, the 4 kHz–6 kHz notches are a practical phenotype for identifying genetic susceptibility to hearing loss; however, more studies are needed to confirm this claim (Majumder 2018). This uncertainty necessitates strict monitoring of occupational noise levels, periodic audiometric check-ups, monitoring of audiogram configuration and the recording of a detailed history of workers exposed to noise (Majumder 2018).

☐ 5.1.2.3. The audiogram and the diagnosis of ONIHL

According to various authors, such as Chau et al. (2012), Dillon et al. (2016), Fredriksson et al. (2016) and Cameron and McBain (2019), pure-tone audiometry is the 'gold standard' of audiometric screening to assess NIHL. Conducting an audiogram for diagnostic purposes requires the skills of highly trained clinicians (Cameron & McBain 2019). Cameron and McBain (2019) assert that the services of highly trained clinicians can be costly and time-consuming as the examination must be conducted in sound-attenuated facilities. Moroe and Khoza-Shangase (2018) conducted a study on the role of audiologists in the management of ONIHL in the South African mining sector. This study's results revealed that audiologists' services are not routinely employed in the mining sector as audiologists are deemed costly.

A standard audiogram (pure-tone audiometry) can be used to differentiate between different types of hearing loss; however, it cannot detect subclinical hearing impairments (Cameron & McBain 2019). As such, additional tests such as otoacoustic emissions (OAEs) and auditory steady state responses (ASSR), which are not routinely included when screening for hearing loss, can be utilised to identify subclinical hearing damage (Cameron & McBain 2019). In South Africa, conducting OAEs and ASSR is not standard practice; however, there have been studies advocating for the inclusion of these measures in the diagnosis of NIHL (Edwards & Kritzinger 2012; Edwards, Van Coller & Badenhorst 2010; Moepeng, Soer & Vinck 2017; Ntlhakana, Nelson & Khoza-Shangase 2020). The use of these sensitive objective measures, which fall strictly under the scope of the audiologists, makes the use of these measures as a preventive strategy impossible within the South African mining context with the current exclusion of audiologists as the leading and core members of the HCPs team.

Cameron and McBain (2019, p. 7) provide a guide to be used to assess and diagnose NIHL in various occupational settings as captured in Table 5.1.

Although Cameron and McBain (2019) proposed this protocol, Vogel et al. (2009) state that while the audiogram is universally accepted as the SRHS, some aspects may differ. These aspects include factors such as patient-related variables as well as types of tests performed, and test conditions may differ as a result of the context in which these tests are conducted. In a systematic review, Schaafsma, Benke and Radi (2010) captured the tests that can be included in an audiogram and how these tests relate to NIHL. The tests included in the systematic review included pure-tone audiometry, transient evoked OAEs, distortion product OAEs, cortical evoked response audiometry, brainstem evoked response audiometry and auditory steady state response.

TABLE 5.1: Guide to be used to assess and diagnose NIHL.

Purpose	Tests
Identify whether hearing or auditory-related impairment are present	Otoscope Audiometry test battery: • Pure-tone audiometry • Otoacoustic emissions tests (screening for subclinical hearing loss) Speech-in-noise test (assess real-world functioning – communication)
Determine whether the hearing impairment is a result of excessive noise exposure	Detailed case history (e.g. history of exposure to hazardous noise, ontological infections or disease, otoscopic abnormalities) Risk factors (e.g. tinnitus, diabetes, smoking and medications) Confounding factors (e.g. age and gender)
Determine the impact of the hearing impairment on the client	Communication skills Social functioning
Develop a treatment and management plan	Select and fit a hearing protection device Assess whether auditory rehabilitation or counselling is required

Source: Adapted from Cameron and McBain (2019, p. 7).

In this review, country-specific variations in how these tests were conducted are provided. Furthermore, this review compared guidelines and methods of assessment in various countries.

The differences in variables speak to the importance of context. In implementing an HCP, either for prevention or compensation purposes, context plays a significant role, as what works in one setting may not work in another setting. To this effect, Moroe (2020) argues that HCPs are CIs and are easily influenced by the context and setting in which they are implemented. The same can be said for audiograms, where there is a consensus that audiograms are the gold standard. However, there will be variations in some tests or variables included based on the context, and there may be variations in the guidelines adopted regarding the method of assessment utilised.

Additional testing can yield valuable information on functioning and communication (Cameron & McBain 2019). Otolaryngologists and audiologists rely on subjective clinical judgements to decide when hearing loss can be attributed to occupational noise exposure. In making this judgement, these professionals should evaluate the worker's history of noise exposure and consider the contribution of confounding factors (e.g. gender, age and race) and risk factors (e.g. smoking, recreational noise exposure, medical history, tinnitus and use of medications) (Cunningham & Tucci 2017; Kirchner et al. 2012; Schaafsma et al. 2010).

A further analysis of the systematic review conducted revealed a lack of representation of LMICs, specifically, African countries. This is concerning as the burden of NIHL is reported to be greatest in sub-Saharan Africa (Hong et al. 2013). When exploring issues of OHS in Africa, there is a dearth of research on contextual challenges and their influence on NIHL (Moroe et al. 2018). Perhaps this is the reason why African countries are not included in the studies explored by Schaafsma et al. (2010). Despite the exclusion in these international studies, in South Africa, eMoyo (2020) summarised the types of audiograms found in the management of NIHL (Table 5.2).

In relation to Table 5.2 the chapter will now discuss audiogram classifications used in sub-Saharan Africa, with a specific focus on South Africa's (PLH and STS) and Tanzania's (UKHSE).

5.1.3. The PLH and classifications of hearing loss for compensatory purposes

In South Africa, in 2001, the Compensation Commissioner's Circular Instruction No. 171 (commonly known as Instruction 171) was introduced as a standard for determination of PD resulting from NIHL and trauma (Manning & Pillay 2020) for compensation purposes in workplaces where there is excessive exposure to noise.

Prior to Instruction 171, Instruction 168 was used to calculate eligibility for compensation (Edwards & Kritzinger 2012). Under Instruction 168, only four frequencies of the audiogram were used to calculate PD and determine compensation. Under Instruction 171, five frequencies of the audiogram were used to calculate the PLH. These frequencies (0.5 Hz to 4 000 Hz) are used in conjunction with weighted, actuarially designed tables to calculate the PLH (Edwards & Kritzinger 2012). Ntlhakana et al. (2020) highlight that in its calculation, the PLH method excludes the higher frequencies which are often the first to be affected by excessive noise exposure. However, for compensation purposes, audiometry records indicate the PLH score, reflecting the loss, despite the PLH weakness or limitations (Ntlhakana et al. 2020).

Before 2003, employers were mandated to have a baseline audiogram for all their existing employees and to settle all due compensation by December 2003. In 'baselining' the existing employees, a deterioration of more than 10% PLH made employees eligible for compensation. To calculate the PLH, a baseline audiogram is required to serve as a reference value for comparison with the periodic measurement (Musiba 2020). In the absence of a baseline audiogram, as was often the case in South Africa, where employees rarely had access to their baseline audiogram, the effectiveness of this PLH approach was not always guaranteed (Musiba 2020).

TABLE 5.2: Types of audiograms performed within the South African industries.

Test	**Type of audiogram**					
	Baseline	**Entry**	**Periodic**	**Monitoring**	**Exit**	**Diagnostic**
Ear pathologies	Concluded before test	Concluded before test	Concluded before test	Concluded before test	Concluded before test	To be diagnosed and treated
Who can conduct the test	Audiologist Audiometrist	Audiologist Audiometrist	Audiologist Audiometrist	Audiologist Audiometrist	Audiologist Audiometrist	Audiologist (diagnosis) Otolaryngologist (treatment) Occupational medical practitioner (treatment)
When the test should be conducted	Within or before 30 days of commencement of work in noise zone	Within or before 30 days of commencement of work at a new site or company	Every six months should the person be exposed > 105 dB, or once a year should the person be exposed to > 85 dBs	Every six months	No more than 30 days prior exit date	On referral to a specialist, after an ear pathology has been identified or hearing loss detected
Which to be compared to	Compare two audiograms (baseline comparison and baseline) not to differ more than > 10 dB at frequencies 500 Hz; 1000 Hz; 2000 Hz; 3000 Hz and 4000 Hz	Baseline	Baseline	Previous audiograms	Baseline	Specialist baseline report
Frequency	Once in a person's lifetime	Every new job site or move to another division where noise is present	As required	As required	Every exit	As required
How many tests done at each appointment	2	1	1	1	1	1–2 depending on the claim present

Source: eMoyo (2020).

The baseline audiogram is used to monitor the hearing thresholds of employees exposed to excessive noise based on the 'better' of two assessments conducted on the same day (Bronkhorst & Schutte 2013). For each ear, the hearing thresholds are compared at 0.5 Hz to 4 000 Hz, the clinically significant frequency area for spoken communication. The difference between the hearing thresholds at each of these frequencies should not exceed 10 dB for them to be regarded as reliable in calculating the PLH to determine the baseline audiogram (Bronkhorst & Schutte 2013). Percentage loss of hearing is calculated for each pair of assessments using frequency-specific tables (0.5 Hz, 1 000 Hz, 2 000 Hz, 3 000 Hz, 4 000 Hz), published in instruction 171. The thresholds of the better and worse ear are used to match the PLH to the frequency-specific table (Bronkhorst & Schutte 2013). Once the PLHs have been calculated and summed for both ears, the test with the lowest PLH is the baseline audiogram. It is a legal document for the remainder of the person's working career, and all future audiograms will be compared to this to monitor the thresholds for hearing conservation and compensation purposes (Bronkhorst & Schutte 2013).

Hearing threshold shifts for hearing conservation and compensation are quantified by the increase in the PLH shift. To determine the PLH shift, also referred to in South African National Standard 10083 as a possible 'PLH shift', the baseline audiogram's PLH is deducted from the audiometry surveillance audiograms. When there is a possible PLH shift of > 10%, a diagnostic baseline audiometry is conducted. The audiologist conducts the diagnostic baseline audiometry and consults the otolaryngologist or an occupational medical practitioner to determine the cause of the hearing loss. If ONIHL loss is confirmed, it is then reported to the compensation commissioner, or the applicable insurance fund, for compensation considerations (Bronkhorst & Schutte 2013).

In 2003, after the baselining of existing employees, and as a response to the high incidence of ONIHL in South Africa, the MHSC intervened by implementing the 2003 Occupational Health and Safety Milestones (Edwards & Kritzinger 2012). These milestones were concerned with (1) eliminating hearing deterioration greater than 10% in individuals exposed to excessive noise and (2) minimising noise emitted by equipment to less than 10 dBA. These milestones were to be achieved by December 2008 and 2013, respectively. The deterioration of 10% refers to the PLH. The PLH was effective as a metric for calculating compensation for hearing loss. However, for hearing conservation purposes, it was ineffective as it focused on quantifying hearing loss for compensation purposes and not for prevention purposes. Therefore, because the milestones were not achieved in 2014, these were revised, and the PLH was replaced by the STS (Ntlhakana et al. 2020).

5.1.4. The STS and classification of hearing loss for prevention purposes

Audiometry testing is an essential component of the medical surveillance system. According to Redelinghuis (2016), audiometry testing assesses and monitors the integrity of an employee's hearing over time while simultaneously availing an opportunity for employers to raise awareness and educate employees about hearing and how to protect it. With this in mind, in 2014, the Occupational Health and Safety Milestones were revised to ensure that (1) no employee's STS exceeds 25 dB from the baseline when averaged at 2 000 Hz, 3 000 Hz and 4 000 Hz in one or both ears; and (2) the total operational or process noise emitted by any equipment must not exceed a milestone sound pressure level of 107 dB(A). The STS is an average shift in hearing of 10 dB or more at the frequencies of 2 000 Hz, 3 000 Hz and 4 000 Hz in one or both ears when compared to the employee's baseline audiogram (Department of Mineral Resources 2016), and it is accepted as an indicator for monitoring of the effectiveness of HCPs implemented in industries (Attarchi et al. 2010).

The STS is considered a more sensitive method of identifying NIHL, as the frequencies used are more specific for NIHL (Booi 2020; Redelinghuis 2016). This method requires two baselines, even if the employee has a baseline under Instruction 171 (Redelinghuis 2016). The STS approach currently applied in South Africa is adapted from the US Occupational Safety and Health Association STS requirements, which use age correction as part of the calculation. However, in South Africa, the STS calculation does not include or account for age correction (Redelinghuis 2016). This amendment has implications in that the contribution of age to hearing loss is no longer being considered. The STS is calculated using three frequencies 2 000 Hz, 3 000 Hz and 4 000 Hz for both ears individually. The results are used to calculate possible losses over time by comparing the baseline to future routine audiograms. Musiba (2020) affirms that the STS as a classification method is better than the PLH. However, this author cautions that the STS as currently implemented in South Africa does not provide procedural information on the steps to be taken to manage the employee, over and above reporting to the employer and counselling the employee. Musiba (2020) argues that this technique is like that implemented by the US OSHA, which also uses the STS. Musiba (2020) notes the following differences between the method implemented in South Africa and that in the USA: (1) the US method has the function for age adjustment of hearing levels utilising the standard tables to factor in ARHL, (2) the US method further specifies instructions on steps to be followed when an STS is identified (Musiba 2020). Musiba (2015) earlier contrasted the US method to the National Institute for

Occupational Health and Safety (NIOSH) method, which promotes the use of a significant threshold shift (NSTS). The NSTS is defined as a 15 dB change from baseline at any frequency (Musiba 2020). According to Musiba (2020) the NIOSH method disregards the correction for age and requires a third audiogram to confirm the STS. When the STS is identified, the NIOSH method gives detailed guidance This guidance includes retraining of employees on noise and its long-term impact, as well as the use of hearing protection and implementation of administrative controls, such as relocating employees to a quieter working environment (Musiba 2020). In his analysis, Musiba (2020) concludes that the NSTS is a superior method. However, despite its merits, this method is only advised and not a legal compliance requirement and its indiscriminate use of any test frequency compromises its specificity in the early diagnosis of NIHL in the workplace. Against this background, Musiba (2020) then proposes the use of the UKHSE method, a method that has been used in Tanzania.

5.1.5. The UK health and safety executive method and classification of loss of hearing for prevention purposes

According to Codling and Fox (2017) the UKHSE method is simple and practical for categorising audiograms and guides practitioners on the appropriate action to take when a threshold shift is detected. This method is based on the summation of the hearing thresholds obtained from all frequencies except 500 Hz and 8 KHz for each ear separately and compares this to reference tables stratified by gender and age to ascertain the degree of hearing (Codling & Fox 2017; Musiba 2020). Four categories are then used to classify the loss and dictate the point of action (Codling & Fox 2017, p. 33):

- Category 1: hearing within normal limits
- Category 2: mild hearing impairment
- Category 3: poor hearing, suggestive of significant NIHL
- Category 4: rapid hearing loss; changes could be caused by noise exposure or disease.

Individuals with Category 3 or 4 should be referred for further management (Codling & Fox 2017). Musiba (2020) argues that this method provides a simple and unambiguous way of classifying audiograms in line with hearing conservation regulations.

Musiba (2020) asserts that age stratification has the benefit of accounting for presbycusis to avoid excluding older employees from gainful employment (Table 5.3).

TABLE 5.3: UK health and safety executive categorisation according to age bands.

Age	Male		Female	
	Warning level	Referral Level	Warning Level	Referral Level
18–24	51	95	46	78
25–29	67	113	55	91
30–34	82	132	63	105
35–39	100	154	71	119
40–44	121	183	80	134
45–49	142	211	93	153
50–54	165	240	111	176
55–59	190	269	131	204
60–64	217	296	157	235
65	235	311	175	255

Source: Musiba (2020).

Musiba (2020) further highlights that the UKHSE, like other methods, is not without its shortcomings. These shortcoming include (1) the lack of consideration of the classical notch at 4 kHz, which is an accepted indicator of NIHL, (2) limited generalisability of this method because it was normed on a predominantly urban Caucasian reference population (Cheesman & Steinburg 2010), (3) poor scientific basis for the justification for gender-based thresholds (Cheesman & Steinburg 2010) and (4) the fact that it is not designed to be used as a diagnostic tool and does not replace the need to thoroughly review the audiogram trace (Codling & Fox 2017). In defence of this approach not considering the audiometric notch, Musiba (2020) argues that the notch and the configuration of the audiogram and all the data used to test the results in other classifications or methods are easily available on the audiogram to supplement the diagnosis. Despite this position, Musiba (2020) concedes the limitation to the use of this method in LMICs such as those in Africa, where there are no specificity or sensitivity tests to compare against, a lack of other available assessment methods and limited occupational clinicians, with referrals that may not be practical in such contexts. In addition, because of few occupational clinicians, otolaryngologist referrals may not be as feasible as they are in HICs such as the UK that have sufficient practitioners.

In providing evidence for the effective application of the UKHSE method, Musiba (2020) draws from a study conducted by Musiba (2015) in Tanzania. This study sought to ascertain the incidence of ONIHL in mineworkers in Tanzania. According to Musiba (2020), prior to the use of the UKHSE method, audiograms in this mine were not classified, and the majority of the cases of NIHL were identified during exit medical examinations. The UKHSE method facilitated the categorisation and classification of historical audiograms, which then yielded the prevalence of NIHL of 47%. This process further mandated occupational health practitioners in that mining company to develop a procedure to immediately classify audiograms after audiometry to inform subsequent steps in the management of at-risk employees (Musiba 2020). Subsequently, employees who exceeded the warning level received comprehensive counselling on noise as a health hazard and on appropriate use of HPDs. Employees who scored above the referral limit were referred to an otolaryngologist for investigation to obtain a diagnostic audiogram. After consulting with the otolaryngologist, employees attended a return-to-work process which included audiometric assessment at a frequency established by the severity of hearing loss and occupational hygiene measurements of their workplace. Employees at high risk were reassigned to work that significantly reduced their risk (Musiba 2020). Musiba (2020) concludes that this method is effective, and it is still the preferred method at the said Tanzanian mine, where it has yielded positive outcomes.

Musiba rightfully points out that the STS method currently used in South Africa does not overtly specify the steps to be taken after conducting an assessment. To that effect, in 2018 at the South African Society of Occupational Medicine (SASOM) conference, Kew (2018) presented legal triggers for action drawn from various legislations, regulations, guidelines and policies on NIHL in South Africa (Table 5.4).

TABLE 5.4: Legal triggers for action in managing noise-induced hearing loss.

Regulation, or legislations or acts	Basis of the action	Action
Occupational Health and Safety Act Section 24 and 25 (prevention) – 1993	Action based on the diagnosis of (or suspicion of) an occupational disease	Report to chief inspector
General Administrative Regulations (8)(1)(b) and (8)(4); (prevention) – 2003	Action based on the diagnosis of an occupational disease detailed in section 25 of the OHSA	Report to chief inspector within 14 days of diagnosis
Compensation for Occupational Injuries and Disease Act ll 171; (compensation) – 2001	The presence of disablement (hearing loss) determined by the PLH calculated from losses at 0.5 kHz, 1 kHz, 2 kHz, 3 kHz and 4 kHz. Action based on PLH shift > 10% from baseline	–
Noise-induced hearing loss regulations (8)(3) (prevention) – 2003	Action based on PLH shift >10% from baseline (disablement)	Employer reports to the provincial director
South African National Standards 10083:2013 (prevention and compensation)	Action based on the contributions of the hearing thresholds at 2.3 and 4 kHz to the PLH value (not on a PLH shift) Action based on PLH shift values 2.3, 6.4% and 10%	–
Mine Health and Safety Act of 1996 (prevention)	Action based on PLH shift of ≥ 5% Action based on STS (2 kHz, 3 kHz, 4 kHz) against audiometric zero (milestone baseline)	–

Source: Kew (2018).
Key: PLH, percentage of loss of hearing; PLH, percentage loss of hearing; OHSA, *Occupational Health and Safety Act of 1993;* STS, standard threshold shift.

Based on Table 5.4, the argument advanced by Musiba (2020) that clinicians can draw from other available information from the audiogram to supplement the UKHSE method, the same can be said about the legal triggers for action being known to clinicians through the various legislations, Acts and regulations. However, access to and utilisation of this knowledge to the benefit of HCPs' goals becomes challenging when qualified knowledgeable clinicians are not the preferred cadre of employees because of perceived costs linked to them, as is the current practice within the South African context, for example.

5.2. Recommendations

Audiograms are used to diagnose and monitor hearing loss. The audiogram gives information on the type, symmetry, degree and configuration of the hearing loss. In occupational audiology, an audiogram can be used to differentiate between high-frequency hearing loss and NIHL based on the configuration of the audiogram. An audiogram was developed to quantify the degree of hearing loss for compensation purposes based on the frequencies most sensitive to noise exposure. However, reading and understanding an audiogram is crucial because decisions regarding the well-being of people exposed to noise begins with an audiogram. Chapter 4 discusses the importance of experience in diagnosing hearing loss and interpreting the audiogram. For conservation and compensation purposes, the American College of Occupational and Environmental Medicine (2003) suggests the following considerations which need to be considered in conjunction with the audiogram:

- Although NIHL typically occurs bilaterally, it may also be asymmetrical, as some sources of noise (for example, sirens and gunshots) result in asymmetrical loss.
- In assessing cases of asymmetric loss, determining a site of lesion to rule out a retrocochlear involvement is critical and necessary before confirming the type and nature of a hearing loss.
- A combined exposure to noise and ototoxic agents including solvents, heavy metal and tobacco smoke has a synergistic relationship and may accelerate the development of a hearing loss.
- Individual susceptibility to the auditory effects of noise varies widely, but the biological basis for this also remains unclear.
- Prolonged noise exposure and the effects of aging may distort the classical 4 000 Hz notch by involving neighbouring frequencies. In older individuals, it may be difficult to distinguish between ARHL and NIHL in the absence of a previous audiogram.
- Individuals with NIHL may experience significant morbidity because of hearing loss, concomitant tinnitus and impaired speech discrimination. On the job, such hearing loss can impact worker communication and safety.

- Depression, social isolation and increased risk of accidents are some of the conditions linked to hearing loss. Therefore, these conditions should be monitored and where possible, an individualised approach should be implemented to avoid further exposure.
- NIHL is irreversible. Therefore, early detection and intervention is the most effective preventive strategy. A 10-dB confirmed threshold shift from baseline, although not necessarily resulting in significant impairment, is an important early indicator of permanent hearing loss. Therefore, workers enrolled in HCPs with noted 10-dB threshold shifts on series of audiometric testing should be carefully assessed and counselled on strategies to avoid noise and on the correct use of personal hearing protection.
- Applying age correction to the surveillance audiograms of workers exposed to noise may result in fewer confirmed 10-dB shifts being reported. Therefore, when applying age correction to the audiometric results of workers with confirmed threshold shifts, the clinician should consider whether a preventable noise component of hearing loss is contributing.

Additionally, Metidieri et al. (2013, p. 209), with regard to making a diagnosis, propose the following:

- In diagnosing NIHL, conclusions should be informed by clinical and occupational research, where prior and current noise exposure is assessed and the characteristic symptoms are considered.
- The diagnostic process must include audiometry investigations and be conducted in a manner that controls the contribution of confounding factors extrinsic to the evaluation. This can be achieved by having a qualified professional (otolaryngologist, audiologist) perform the assessment and instruct the patient to perform sound rest for 14 h (context-specific) before the hearing assessment.
- The health care professional conducting the evaluation must also pay attention to confounding factors intrinsic to the assessment such as the patient’s general condition, motivation, intelligence, attention, familiarity with the task and interpretation of the test instructions.
- Exposure data should be recorded to highlight the correlation between the exposure and the signs and symptoms of NIHL as this serves as an essential tool for risk identification.
- Regular site visits should be conducted to understand the working conditions, review the company’s technical reports, obtain information from past inspections and from the patient’s report.
- Baseline as well as previous audiograms should be compared with the current assessment to determine the presence of progressive hearing loss, if any. Additionally, cases of stable exposure to noise generally plateau within approximately 10–15 years, these should be noted and monitored.
- NIHL should be differentiated from other auditory pathologies that have different characteristics despite having the same aetiology and possibly occurring in association with the work environment.

- There is currently no treatment for NIHL. Preventive strategies are instrumental in limiting the damage by enrolling workers in health surveillance programmes and monitoring the progress of hearing loss through periodic audiological evaluations.
- Noise is a known occupational hazard; as such, preventive measures must be implemented in the workplace.
- Strategies to control NIHL should align with noise control hierarchy and focus on controlling exposure at the source, trajectory and individual levels of exposure. Furthermore, administrative controls, such as reducing travel, establishing breaks and rotating shifts through the noisy area, should be implemented.

5.3. Conclusion

The use of the audiogram in HCPs as deliberated on in this chapter, with the history and the development of the audiogram, as well as the development in the classifications of the audiogram, highlights the importance of continual engagement with this arguably ‘standard’ knowledge. The changes have significant implications for practice in HCPs and should consider potential changes linked to advances in platforms of audiology service delivery such as tele-audiology, the impact of automation and digitalisation (as presented in ch. 7) and so on. This must be done bearing in mind considerations for practitioners in the diagnosis of NIHL.

Chapter 6

Hearing conservation programmes and the industrial revolutions

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6.1. Introduction

Industrial revolutions, from the first to the last, have brought about technological, knowledge and science advances. These advances have facilitated ground-breaking innovations and transitions from manual labour to powered machines, steam engines, mechanisation and, ultimately, easy access to the Internet, information technology and artificial intelligence (AI) (Ali & Frimpong 2020; Sánchez & Hartlieb 2020). Commercially, these revolutions have opened doors to global industries, employment prospects, and capital investments (Min et al. 2019).

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The IRs have led humanity to the current edge of a technological revolution that has the potential to profoundly change the way we relate to one another and how we live and work. From the First Industrial Revolution (1IR), where steam and water power were utilised for production mechanisation, to the Second where electric power became the source for creating mass production, then to the Third (digital revolution), which adopted information technology and electronics for production automation, to the current 4IR; obvious significant changes to the way of being are evident. The 4IR, building on the Third, is distinguished by a fusion of technologies that is making it difficult to discriminate between the digital, physical and biological fields (Schwab 2016). As exciting as this might be in terms of opportunities that it brings, such as increasing income levels and enhancing the quality of people's lives globally where affordability and access to the digital world is not a challenge (Schwab 2016), significant challenges are also possible. Besides the 4IR's anticipated capability to yield greater inequality, particularly in its potential to unsettle labour markets, other important challenges need to be considered as they would impact ONIHL and HCPs implementation. Although some argue that automation substitutes for labour across the entire global economy may worsen and widen the income gap as employees will be displaced by machines, it is also possible that this employee displacement by technology will yield positive gains as far as OHS are concerned (Schwab 2016).

When focusing on health and safety of workers, while noise was always present, the revolutions intensified its impact and exposed workers to OHS hazards, including ONIHL. Efforts to minimise the worker's exposure to hazardous occupational noise, in the form of various hearing conservation strategies, were also influenced by the IRs. As such, the current 4IR has been argued to have brought about cost-effective and easily accessible hearing conservation strategies. This chapter maps the journey of IRs and their influence on OHS, with a focus on their contribution to excessive noise in the workplace. This is then followed by a discussion on the influence of these revolutions on HCPs. The 4IR and advances in HCPs is then deliberated, with considerations around the 4IR in HCPs highlighted.

The 4IR is the epoch of modern and recently developed technology focusing on information and communication (Min et al. 2019) and a term that was invented by Klaus Schwab, creator and Executive Chairman of the World Economic Forum (Dimitrieska, Stankovsk & Efremova 2018; Lee et al. 2018; Xu, David & Kim 2018). Klaus Schwab describes 4IR as the 'current and developing environment in which disruptive technologies and trends such as the Internet of Things, robotics, virtual reality and AI are changing the way people live and work' (Dimitrieska et al. 2018, p. 182). Simply put, 4IR is 'a world where individuals move between digital domains and offline reality with the use of connected technology to enable and manage their lives' (Xu et al. 2018, p. 90). Experts have said that industries and populations need to be well prepared for the 4IR, as its advent potentially influences how people work, consume and think (Schwab 2016).

Min et al. (2019) argue that compared to the past, 4IR is more economically responsive. However, this also presents uncertainty for labour markets, as machines that are advanced in technology may replace human labour, thereby offsetting total factor productivity. Min et al. (2019) describe how the 1IR transformed physical labour with the advent of a steam engine, while the Second Industrial Revolution (2IR) introduced the manufacturing of large quantities of products using electric energy (Hull 1994). The Third Industrial Revolution (3IR) then ushered in the automation era, where new communication technologies were computerised and Internet-based (Toffler & Alvin 1980). Min et al. (2019) assert that henceforth, the superintelligence revolution informed by the Internet of Things, cyber-physical system and AI will greatly revolutionise human intellectual labour (Bloem et al. 2014).

Schwab (2019) highlights that the 4IR will bolster and eventually impact working conditions. Min et al. (2019) describe how because of the fact that relaxation of labour regulations was brought about by globalisation, companies exploit workers in LMICs, including in the African continent. This exploitation is done to increase productivity of their companies, leading to workers in LMICs working in unsafe occupational settings without proper welfare or adequate compensation, under increased maximum working hours because of potential increases in shifts or night shifts. Shift work has been reported to cause circadian rhythm disturbances by change of melatonin (Touitou, Reinberg & Touitou 2017), and it increases the threat of breast cancer (Jia et al. 2013; Schernhammer et al. 2006), cardiovascular and cerebrovascular diseases (Vyas et al. 2012), type II diabetes (Knutsson & Kempe 2014; Koo et al. 2016) and depression disorders (Bara & Arber 2009; Lee et al. 2016). Chapter 3 describes the influences of all these factors as risks for ONIHL.

These negative outcomes are also accompanied by positive influences of advances in technology. Evidence has been published that indicates that the 4IR, through automation, may remove workers from harmful workspaces (Min et al. 2019), and this can be extended to removal from excessive noise exposure areas. Chen (2012) provides an example that shows that through new technologies, hazardous conditions such as chemical leaks or work-related accidents can be averted in real time through AI, where human behaviour can be detected through security cameras. These authors claim that with this technological advancement, if a situation that is dangerous or hazardous to the employee is detected, the relevant system can raise an alarm and alert the relevant personnel timeously to avert the accident in advance. The authors of this chapter argue that excessive hazardous noise exposure can be included in this monitoring and the employee be warned to either avoid the area and or insert their PPE in the form of HPDs. Rejeb et al. (2021) and Le, Pedro and Park

(2015) report on the application of simulated 3-dimensional environment (virtual reality) technology and augmented reality glasses in OHS education and argue that these technological advances can improve the effectiveness of education in OHS.

Some of the rapid advancements in technology have also been noted to allow for protection of workers from developing ONIHL because of high levels of noise at work. This is via advances observed in the methods and tools utilised such as smartphone apps, low-cost sensors, the Internet of Things, 3-dimensional printing or modelling, as well as data mining (Brauch 2017; Ntlhakana et al. 2021).

6.1.1. Industrial revolution and noise-induced hearing loss in the workplace

Arguably, each IR can be considered as a separate event; however, Dimitrieska et al. (2018) argue that it is best to view and consider these revolutions as a chain of events where one revolution leads to the next, and the next feeds on the innovations of the previous one. What follows is a brief overview of each IR with its contribution to industry, followed by the history of hearing loss in relation to the various IRs.

6.1.1.1. First Industrial Revolution

The 1IR commenced in 1760, with the advent of the heat or steam engine that replaced manual work (Dimitrieska et al. 2018; Min et al. 2019; Xu et al. 2018). The advent of steam engines brought about the transition from farming using coal as the primary source of energy, with locomotives as the primary source of transportation. Commercially, textile and steel became the leading manufacturing industries with prospects in employment, value of output and capital investment (Dimitrieska et al. 2018; Xu et al. 2018). According to Dimitrieska et al. (2018), the most significant invention of this period was the steam machine that enabled mass manufacturing of products with low energy usage. Moreover, this was a period of transportation progress, as well as advances in science and technological developments, such as the use of: (1) iron and steel, (2) new sources of energy, fuel and coal, (3) significant developments in communication and conveyance of goods via trains and (4) the surge in the utilisation of science in industry (Dimitrieska et al. 2018).

6.1.1.2. Second Industrial Revolution

The 2IR began in 1900 (Xu et al. 2018) and is marked by the creation of the internal combustion engine, which ushered in the use of electricity and oil to mechanise high-volume production (Dimitrieska et al. 2018; Xu et al. 2018). Hull (1994) states that the 2IR capacitated high-volume production through electric energy. This period introduced new innovations such as the telephone, radio, telegraph, diesel and gasoline engines, electricity, internal combustion engine and X-rays (Dimitrieska et al. 2018).

6.1.1.3. The Third Industrial Revolution

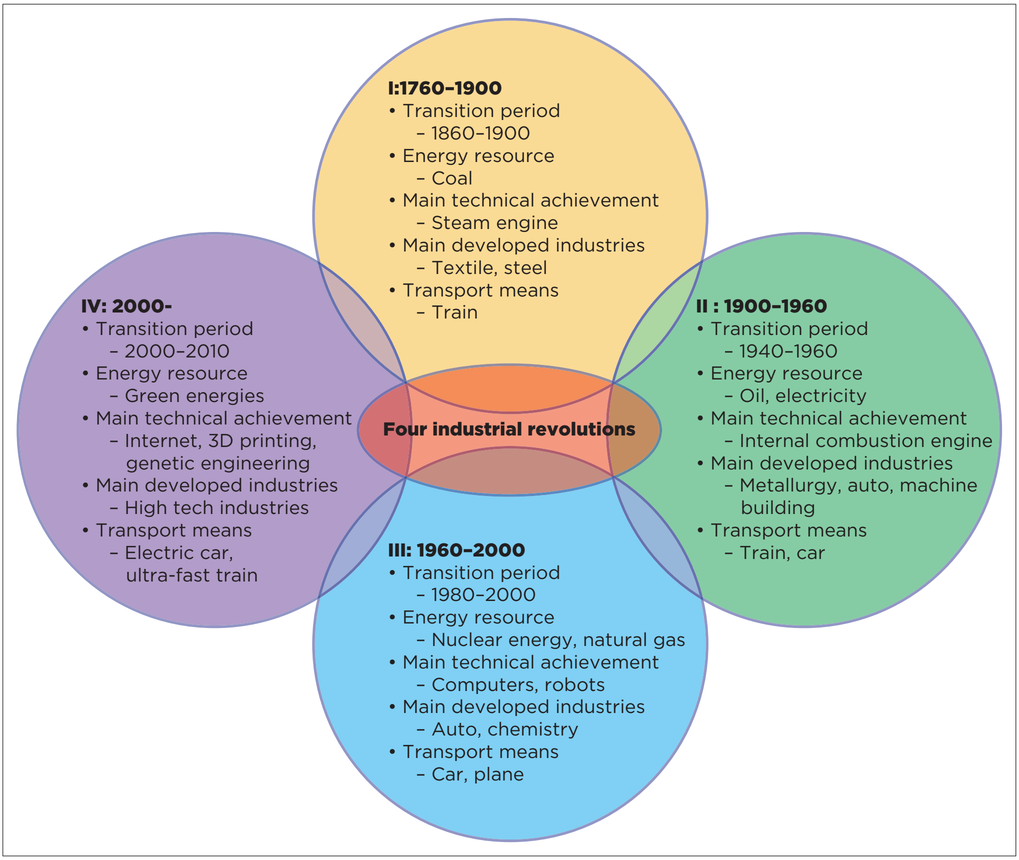
The 3IR, which emerged in the 1960s, was characterised by the move from traditional industry to an economy driven by information and communication technology (Dimitrieska et al. 2018). This period was known for introducing and utilising electronics and information technology that enabled automated manufacturing of goods and products (Xu et al. 2018).

6.1.1.4. Fourth Industrial Revolution

Globally, populations are presently living on the threshold of the 4IR, which commenced at the cusp of the 21st century and thrives on the digital innovations (Dimitrieska et al 2018). This era, the 4IR, is characterised by the ever-present and affordable mobile Internet, nanotechnology or sensors and by AI and machine learning (Min et al. 2019; Ntlhakana et al. 2021). Dimitrieska et al. (2018) describe this era as a kind of amalgamation of technologies of physical, digital and biological platforms. Reportedly, the 4IR aimed to usher in concepts such as a smart factory which are flexible, efficient and integrate consumers and business partners into the business process (Dimitrieska et al. 2018). This revolution is slated to shepherd in economic development touted to optimise the quality of life and standard of living by incorporating production, marketing and users with the best communication technologies and engineering advances (Dimitrieska et al. 2018). Its success is linked to the ‘big data’ concept, a technology that combines the collection and processing of large amounts of data (structured and unstructured) in real time (Dimitrieska et al. 2018; Ntlhakana et al. 2021). Xu et al. (2018) provide a summary of the IRs with the transition periods and the main technical achievements, and this is summarised in Figure 6.1.

6.1.2. Occupational noise-induced hearing loss and the various industrial revolutions

Numerous studies have been conducted to document the history of ONIHL. From these studies, there is consensus that it is not known with certainty when people first realised that excessive noise could cause permanent damage to their hearing (Thurston 2013). Thurston (2013) suspects that in the Bronze Age, metalworkers would have been aware that noise produced by their tools may have cause changes to their hearing acuity. What is certain



Source: Figure created by MR Shangase, adapted from Xu et al. (2018, p. 91).

FIGURE 6.1: A summary of the industrial revolutions with the transition period and the main achievements.

is that by the 20th century, metalworkers realised that noise was not only a nuisance but was also detrimental to their hearing health, but the number of metalworkers in the Bronze Age who acquired hearing loss was unknown (Thurston 2013). In support of this, Hedeen (1980) claims that, comparatively, before the introduction of the 1IR, a significantly low number of workers were exposed to hazardous noise at work. Thurston (2013), however, argues that some occupations such as coppersmiths and blacksmiths were noisy, but exposure was limited to only a few metalworking artisans within the workshop. According to the National Academy of Engineering (2010) work-related exposures are as a result of working closer to equipment and machines traditionally used in industries with excessive noise. Loss of hearing stemming from occupational noise exposure is the most prevalent industrial exposure, with the damaging effects of excessive noise on hearing having been reported as early as the 13th century, alongside the invention of gunpowder (Thurston 2013). However, despite these earlier reports, hearing loss was officially only first documented by Bernardo in 1713, before the 1IR (National Academy of Engineering 2010; Ramazzini 1964; Thurston 2013). In subsequent centuries civilians realised that loss of hearing occurred after short-term exposure to gunpowder and cannon fire (Thurston 2013). As early as the 19th century, because of the reported cases of hearing loss in seamen and subsequent cases as a result of sport shooting and the First World War in the mid–19th century, the term 'gun deafness' was coined (Thurston 2013).

The innovation of gunpowder and the 1IR reframed noise in the workplace as an occupational hazard (Agarwal et al. 2015). Inevitably, this evidence indicates that ONIHL became the unintended consequences of the 1IR with its introduction of new machinery (Agarwal et al. 2015). Soon after, ONIHL was observed in artisans who manufactured steam boilers (1IR) (Agarwal et al. 2015; Azizi 2010; Nair 2014). Increasing mechanisation and industrialisation compounded the noise problem in the workplace (Hedeen 1980). Furthermore, the introduction of mechanised factories resulted in hundreds of workers being exposed to noise at a time, instead of a few, as was the case before the industrialisation (Thurston 2013). The noise in the factories was acute, and it could be heard from a distance; consequently, some municipalities relocated factories to the outskirts of the cities to contain noise pollution (Thurston 2013).

During the 2IR that followed, industry saw the emergence of the internal combustion engine, which exacerbated hearing loss among workers, not only through exposure to loud noise but through vibrations as well. Chapter 3 presents risk factors that influence ONIHL, including the interaction of excessive noise exposure and vibration. According to Heywood (1988) and Santana, Barros and Junior (2014), internal combustion engines, by design, transform mechanical energy in fuel into mechanical energy by burning the fuel-air mixture. As a result of the constructive and functional characteristics of the engine, this combustion lands itself as a (Santana et al. 2014):

> [*M*]ajor source of noise and vibration of the vehicle, because the engine is run through the vibrations and noise is transmitted to the body and is felt by the occupant of the vehicle. (n.p.)

Additionally, by the 19th century, electrically operated communication devices were invented and were subsequently blamed for causing hearing loss among the telegraph operators, who complained of the clicking noise emitted by the earpiece of the telegraph receiver (Thurston 2013). Another big industry that was not spared the exposure to and effects of noise was the mining industry.

Thurston (2013) argues that the mining industry is consistently the most hazardous industry, with workers exposed to a variety of risks, including noise. Before the 1IR and the powered machinery to drill and blast rocks, hammers and striking chisels would have been the main source of noise, which was not regarded as a significant risk for the miners (Konya 2020). It was in the late 19th century when powered machinery was installed that noise levels reportedly increased (Angliss 1998). To date, ONIHL remains the most prevalent occupational condition across different industries (Mirza et al. 2018; Ntlhakana, Nelson & Khoza-Shangase 2020). In fact, approximately 16% of cases of hearing loss are associated with exposure to hazardous exposure to occupational noise (Beyan et al. 2016; Zhou et al. 2020), with the prevalence ranging from 7% in workers residing in HICs (Nelson et al. 2005; Zhou et al. 2020) to 21% in LMICs (Nelson et al. 2005). With the negative influences on hearing function being associated with the 1IR, advances in the protection of workers exposed to high levels of occupational noise have also been linked to it.

6.1.3. Industrial revolution and hearing conservation programmes

Interestingly, according to Thurston (2013), historically, some physicians and social workers understood the effects of noise and subsequent hearing loss; however, they could not implement or offer effective strategies to minimise or eliminate the problem until the mechanisms of injury and engineering designs for quieter machines were better understood. It was only in the 20th century that the chief medical inspector of factories in Belgium recommended periodic hearing tests on workers exposed to excessive noise, with the hope of moving them to less noisy jobs before they developed hearing loss (Glibert 1922). Thackrah (1832) discussed the health risks associated with occupational noise and suggested the use of cotton earplugs to minimise the effects of sound waves on the eardrum. This author rationalised that the cotton wool would soften the sounds and protect hearing. However, there was minimal clarity on whether the cotton wool should be inserted moist or dry and the degree of protection expected. Consequently, there was not much buy-in from the industry for this preventive measure (Thurston 2013). Despite the lack of consensus on the effective method to use to prevent ONIHL, there were ongoing engagements on understanding the noise and its effect on the well-being of the workers. Consequently, there was a suggestion to use India rubber earplugs, similar to cotton earplugs, as protective devices. Relatedly, there was poor acceptance of the use of these earplugs because of concerns that they would compromise verbal communication, thus increasing the risk of injury to the workforce as it would be hard to hear orders and warning signals (Glibert 1922). Consequently, there were concerns about the lack of compliance on the use of personal HPDs, despite them being mandated by safety regulations (Suter 2002).

It was only in 1948, after World War II, when soldiers returned from war with hearing loss, that regulations on hearing conservation were formally implemented, starting with the Department of the Air Force (Berger et al. 2003). Since then, HCPs have undergone several modifications and reviews, as reflected in Table 6.1. These changes include the terminology used to refer

TABLE 6.1: Advances in hearing protection from World War II to the present.

Time frame	Typical devices	Comments
World War II	Cotton	Minimal noise reduction
	Fingers	Effective but inconvenient; used by artillery crews occasionally
	Nothing	The standard of the day
1945–late 1950s	Vaseline-impregnated cotton	Messy, modestly effective, better for water protection than noise protection
	V-51R earplug	Initially produced in three sizes; developed just at the end of World War II
	Hard custom ear-moulds	Poor seal; not routinely used
	Early circum-aural earmuff designs	Initial designs had inadequate cushions and modest attenuation (around 20 dB or less) up to 1000 Hz
	Navy 'cranial earmuffs' introduced in mid-1950s and still in use today (circa 2005)	Plastic earmuff cups held in place by fabric head cap with a plastic shell covering the fabric but not enclosing the earmuff cups; inadequate fitting and modest protection
1960s	V-51R earplug	An extra-small and extra-large size added to fit a wider range of ear canals
	Triple-flange earplug	Alternative easier-to-fit design introduced as a two-sized version
	Canal caps (pods on light-weight band)	Modest protection for intermittent environments
	Malleable putty earplug	Not widely used, and ergonomic problems because of required kneading and messiness
	Improved earmuffs	Higher attenuating designs introduced with better cushions and headbands
1970s	Conventional plugs and muffs same as 1960s	Technology essentially matures by this time, but some material improvements such as newer three-sized silicone version of triple-flange plug. Also, colour-coded sizing introduced
	Roll-down slow-recovery foam earplugs	New-concept earplug that provided better protection and comfort, but limited use in military initially
	Tanker helmets and aircraft flight helmets with internal earcups for noise attenuation	Helmets began to provide not only impact protection, but acoustical protection too. Low-frequency attenuation not as good as conventional earmuffs
1980s	Conventional plugs and muffs same as 1960s and 1970s	No technology advances
	Tanker helmets began to appear with ANR included	ANR in this environment improved communication and protection
1990s	Same as prior decades	Minor technology advancements especially in cosmetics, but performance essentially unchanged
	Widespread use of roll-down slow-recovery foam ear plugs	Most commonly used hearing protection device
	Communication earplugs	Use of earphone in foam earplugs for use in tanker and helicopter applications for enhanced communication under helmet and increased protection
	Widespread use of ANR for tanker helmets and limited application of ANR for aircraft flight helmets	The advantages of ANR began to appear in aircraft applications too
2000–present	Same as prior decades	As before, except that V-51R plug dropped from inventory
	Level-dependent 'combat arms' earplugs	New technology provides the ability to protect against weapons and blast noise but still allow communication and signal detection of lower-level sounds when the impacts are not present

Key: ANR, active noise reduction.
Source: National Academy of Engineering (2010, pp. 166–167).

to the HCPs (Berger et al. 2003), the permissible noise exposure level (Moore & Lusk 1997) and the pillars that HCPs must comprise of (Moore & Lusk 1997). Evidence suggests that the success of HCPs is largely influenced by adherence to all the pillars of the HCP (Amedofu 2007; Hong et al. 2013; Khoza-Shangase, Moroe & Edwards 2020). These include periodic noise exposure monitoring, engineering controls, administrative controls, personal hearing protection, audiometric evaluations, employee and management education and training, as well as record-keeping (Amedofu 2007; Moroe et al. 2018). The modifications to HCPs, as tabulated in Table 6.1, seemed to indicate that HCPs are CIs, aimed at minimising or eliminating ONIHL (Amedofu 2007; Moroe 2020; Moroe & Khoza-Shangase 2020; Moroe et al. 2019). Furthermore, the modifications revealed that implementation of interventions requires careful consideration of the context (Khoza-Shangase et al. 2020), as well as use of preventive approaches that are predictive in nature (Khoza-Shangase & Moroe 2020a; Moroe et al. 2020; Ntlhakana & Khoza-Shangase 2022), allowing for early detection and therefore early intervention.

6.1.4. The 4IR and advances in HCPs

Evidence that swift developments in technology is changing the way people work and live and wields an impact on personal and professional lives exists (Brauch 2017). Not only are these advances seen in the commercial products, but they can also be seen in the buy-in by government agencies and the military in stimulating and supporting innovations to develop advanced tools for practitioners dedicated and tasked with the health and safety of workers exposed to hazardous noise in the workplace (Brauch 2017). Consequently, HCPs are evolving faster, and this evolution is driven by best practice and new technology, including engineering and administrative controls, risk and exposure assessment, as well as PPE (Brauch 2017; Moroe & Khoza-Shangase 2020). To keep up with 4IR in protecting workers from excessive noise in the workplace, Brauch (2017) lists three areas of substantial improvement: (1) new technology, (2) HPDs fit-testing and (3) smartphone aid in measurement.

6.1.5. Technological improvements (new technology)

Conceptually and logically, engineering controls in the form of ‘buying quiet’ is the first line of defence against ONIHL, the gold standard of preventive health care in HCPs (Brauch 2017; Khoza-Shangase et al. 2020; Moroe et al. 2019; NIOSH 2016). Practically, these engineering controls are expensive for the employer; consequently, the adoption and uptake of these interventions is suboptimal (Rupprecht 2017). Khoza-Shangase (2022) argues that ‘buying quiet’ is an important primordial prevention strategy that should be prioritised in LMICs, such as the African context. Primordial prevention comprises of initiatives aimed at changing and or addressing population health determinants and preventing development of factors (in this case, excessive noise generation) that are known to increase future risk of the disease or condition (ONIHL). To this end, Brauch (2017) proposes the use of 3D printing, which is more adaptable, financially reasonable and quieter, to replace the traditional noisy machines among other such strategies for reducing and or eliminating noise from the source.

On the hierarchy of HCPs pillars, after engineering controls, the next line of defence is the use of administrative controls (Moroe & Khoza-Shangase 2020; NIOSH 2016). Brauch (2017) argues that administrative controls strategies can be analysed in advance for optimal effectiveness through online and free task-based exposure modelling software tools. Additionally, there are programmes that can be used to analyse trends in individuals' HTL in relation to the reported noise exposure levels, types of hearing protection used, medical histories and years of exposure. These are predictive models that are meant to facilitate earlier identification to achieve *preventive* outcomes, rather than *compensation* outcomes (Moroe et al. 2020; Ntlhakana et al. 2021). Brauch (2017) argues that if implemented as intended, these programmes can predict which employees are at risk of developing compensable hearing loss.

Personal protection devices are the last line of defence against ONIHL, but they are often used as the first and only preventive strategy in most workplaces. There are new types of passive and active protective devices which come with wearable real-time noise alerts to ensure that employees are wearing their protection in noisy environments (Brauch 2017). These are in line with what Chen (2012) describes as important technological advancements to enhance OHS that facilitate the prevention of harm in advance by real-time monitoring of the environment. This is so that if a dangerous or hazardous situation to the employee is detected, an alarm is raised for all relevant stakeholders, including the worker. As far as HCPs are concerned, Brauch (2017) also makes reference to a sound monitor that is small enough to be mounted on the worker's eyewear with an optical display depicted like a 'heads-up' display for jet fighters and high-end sports cars, which allows the worker to real-time monitor their noise exposure levels.

6.1.6. HPDs fit-testing

Hearing protection device fit-testing, also termed the field attenuation estimation system (FAES), is an advancement in HPDs that is applied to determine the effectiveness of a HPD for an employee when worn correctly (Biabani et al. 2017; Hager 2011). Hearing protection devices fit-testing is gaining global adoption for fostering correct use, Internet-based hearing acuity tests and hearing loss simulation (Brauch 2017), with minimal evidence of its use in LMICs. A most recent advancement in HPDs fit-testing has been the arrival of the optical scanning technique, an option to silicone ear impressions. Traditionally, custom-fit HPDs are administered by a technician or audiologist, through injecting liquid silicone into the ear canal. 4IR has introduced a technique where accurate light-based methods are used to scan the ear canal in one manoeuvre, allowing for quick and accurate ear mould printing. This technique is made possible by the latest developments in digital imaging, 3D modelling and low-cost high-speed processing ability. The scanned ear canal files are then printed as moulds for custom-fit HPDs using high-resolution 3D printers (Brauch 2017). The efficiency that this advancement introduces facilitates early intervention, where workers do not have to wait for long periods for their custom-made HPDs to be delivered or where workers do not have to go without HPDs in instances of loss or damage to their devices.

6.1.7. Smartphone aid in measurement

Undoubtedly, the transformation of smartphones into powerful pocket-sized computers has made affordable noise measurement possible, as numerous applications which offer detection measurements of A-weighted sound pressure levels are now easily available for most devices (Brauch 2017). This advancement has introduced dosimeters and sound level meters that are digitally sampled and utilise Bluetooth remote communication features that allow for both noise and motion sensing in the employee, with recording features (Brauch 2017). This also allows for tele-HCPs to be implemented either synchronously or asynchronously – as extensively covered in Chapter 10.

Furthermore, for workers suffering from tinnitus as part of their ONIHL symptoms, there are applications such as signal and tone generators that can be used to create sounds or noises for masking background noise in the room to create auditory stimulus relief for people suffering from tinnitus (Brauch 2017). Other applications simulate the audiometer functions, and although these are not yet calibrated for compliance in HCPs, they are instrumental in raising awareness of possible hearing loss, as results may indicate a need for a properly administered audiogram by an audiologist (Brauch 2017). Brauch (2017) cautions that applications vary in accuracy; the most accurate are not freely available, and most use the smartphone microphone instead of true precision measurement microphone as mandated by the American Occupational Safety and Health Association. These warnings raise implications for research in the use of these apps within HCPs, for cost and time effectiveness. They also raise implications for addressing the capacity versus demand challenges that exist within LMICs as far as audiologists-to-population-size availability is concerned. More information on the 4IR advances, including the use of models and AI in the management of ONIHL can be obtained in Chapter 7, where changes from manual to fully automated systems and the impact of AI in mining on ONIHL are covered in detail. The contribution of technology in facilitating hearing protection is a worthwhile recent development in hearing conservation in youth (Khan, Bielko & McCullagh 2018) as well as in workers exposed to hazardous noise at work. Although, according to Khan et al. (2018), there are fewer studies that have documented the use of technology in HCPs for reaching larger and hidden populations in cost-effective ways, Khoza-Shangase and Moroe (2020b) strongly argue for capitalisation on these technological advancements to increase access to audiological care within the African context via tele-audiology. The role of technology in promoting healthy behaviours, such as preventive audiology in ONIHL, should not be undermined as some technology-based programmes have shown considerable efficacy, as presented in Chapter 10.

6.1.8. Considerations for 4IR and HCPs

Without a doubt, the technological revolution has altered the way we live, work and relate to each other as almost every aspect of human lives has been impacted by 4IR (Petrillo et al. 2018; Schwab 2016). 4IR has introduced transformation of unknown boundaries, scale, complexity – a phenomenon not previously experienced by humankind. This industrial era is a combination of technologies, thereby creating fluidity between the physical, digital and biological spheres. This fluidity calls for critical, integrated and comprehensive reflection on how practitioners respond to the current revolution. This is because 4IR is not without its negatives and limitations. This is why consumers of 4IR reflect and consider how they respond to the changes brought by technology. Specifically, it is important for all stakeholders to uphold an ethical impetus in the application of technological advances to ensure the moral foundation of future generations (Petrillo et al. 2018). Huizingh (2011) argues that only ethics can ensure humanity; as such, ethical issues must undergird the application of advances in technology.

One critical area of concern in the development and implementation of HCPs is employment. 4IR has introduced AI, which has introduced unprecedented new levels of productivity and transformed jobs (Chu & Majumdar 2012). Artificial intelligence is discussed in more detail in Chapter 7. With the advances in technology, human labour has been replaced by automation, to the disservice of workers with limited education and skills (Maynard 2015). In the African context, the mining industry is one of the leading employers. Historically, the mine's workforce was previously disadvantaged with regard to education and skilled labour (Kane-Berman 2017;

Smit & Mji 2012). In South Africa, the rate of unemployment is currently at its highest. In 2006, Smit and Mji (2012) reported that 67% of the South African mineworkers had education levels below Grade 7, and a quarter of this population had no formal education. Therefore, replacing human labour with automation has implications for the mine's workforce and their families. Bloem et al. (2014) urges that organisations and governments pay attention to the changing needs of work and ensure that training, upskilling and career reinvention are provided to avoid technology significantly affecting people's jobs and livelihoods.

Another ethical consideration around the 4IR is that of equality. The 4IR and ethics has improved income levels and the quality of life for people (Huizingh 2011). However, the economic benefits of the 4IR are focused on a small group of people, thereby increasing inequality. In the South African mining industry, as alluded to the majority of the mine's workforce comprised mostly of black males with limited education and skills. It therefore follows that embracing the 4IR will benefit the privileged few, at the expense of the people who do the actual manual labour. The effects of low levels of education and unskilled labour have left a negative legacy, as seen in the renumeration of black workers in the mining sector. Kane-Berman (2017) elucidates that historically, the average salary of a white worker was 16 times more than that of a black worker. If these past injustices are not redressed, introducing and embracing technology will widen the inequality gap among the workforce. Furthermore, this gap may also be witnessed within the industry, where small-scale mines may not have the same resources as large-scale mines. Huizingh (2011) recommends that companies commit to more inclusive development and equitable growth for all people and the benefits of new technologies must be evenly distributed across all demographic groups.

Lastly, another consideration regarding the 4IR is how privacy and trust are managed. Lasi et al. (2014) cautions that technology has widened the scope of surveillance and compromised privacy. With the advances in technology and the use of smartphones in the management of ONIHL in particular, Brauch (2017) discusses the use of digital dosimeters and sound level meters. These devices store data and there is a potential that the data may be used against the workers who may not fully comply with the regulations. This may deter workers from wanting to use these devices to protect themselves from excessive noise exposure. In this regard, Petrillo et al. (2018) warns that 4IR technologies, while neutral, work increasingly in ways that compromise worker trust. Therefore, there is an urgent need to consider and ensure high levels of trust and privacy now and in years to come. This privacy and trust also extend to ethical standards adherence in health care such as privacy and confidentiality, as well as observance of the PoPIA.

In conclusion, the 4IR is defining humanity and has the potential to impact people's lives, thus necessitating the need to implement ethical considerations to monitor technologies for the benefit of the human race. In particular, the impact of technology must be addressed in relation to the issues of equality, employment, privacy and trust (Petrillo 2018).

■ 6.2. Conclusion

Sutherland (2020) laments how, within the South African context, President Cyril Ramaphosa's placing of the 4IR into his national economic strategy generated criticism because it was believed that the 4IR echoes neoliberalism and that it would not create jobs, which is a significant South African socio-economic challenge. This author states that South African companies dreaded that the 4IR intends to reconsider the auto-cannibalisation of business models as well as strategies, as opposed to policymakers in production countries understanding that it is designed to bring production home and elevate national competitiveness, potentially obstructing LMICs from developing employment by promoting labour-intensive manufacturing. Accordingly, the influence of the 4IR on work and jobs are predicted to be complicated, with a significant potential to raise inequality by lowering the necessity for low-level skills. This is a considerable challenge for South Africa, where the majority of the workers possess low-level skills. Furthermore, problems of poor-quality infrastructure, poor record in policy formulation and implementation and delays in cybersecurity and data protection have been highlighted as influencing the 4IR in Africa (Michaud 2019).

Bearing in mind the previous discussion, in presenting this chapter in the manner that the authors have, there is acknowledgement that significant evidence presented has not reached the African continent, with IR lags in health care delivery and in African mining industry having been well documented. However, Michaud (2019) highlights the need for African mines to deliberate on both challenges and opportunities linked to the IR and the involvement of the mining sector in it – paying particular attention to the 4IR. As far as opportunities are concerned, this author highlights that within the South African context:

1. Digitising of the mining industry and the economy at large presents an opportunity to upskill and re-direct the workforce into technology-driven occupations such as data mining and data analytics.
2. Increased efforts and investments should be focused on research and development.
3. Platinum mining should be capitalised on and play an important role as the energy and mobility sectors transition to a hydrogen economy.

4. Collaborative approaches should be adopted in order not only to reap the benefits of 4IR economically, but to ensure that all aspects involving mining are attended to.

The current authors believe that the African audiology community needs to be part of these important developments and deliberations to ensure that HCPs challenges are addressed and the workers across the continent with a risk of ONIHL benefit from the technological advancements gained.

Chapter 7

From manual to fully-automated systems and the impact of artificial intelligence: Effects of changes in mining practices on occupational noise-induced hearing loss in Africa

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7.1. Introduction

The past 100 years have seen a significant shift in methods and systems used in mining, from manual towards fully automated systems. This shift has included advances in the use of AI. These changes have an impact on ONIHL and the preventive strategies in place in the form of HCPs. This chapter deliberates on these changes by presenting the evolution of the mining machinery and transportation in Africa and how this has affected the presentation of ONIHL. The dynamics of change of machinery and transportation methods from manually operated systems to mechanisation and finally to the development of fully automated machinery and transportation vehicles with AI are discussed. The authors argue that fully automated mines will result in mineworkers, both in surface and underground mining, having minimum interaction with the mining environment. This will lead to less exposure to hazardous noise levels, with a consequent reduction in prevalence and severity of ONIHL within this context. This chapter uses two case examples to illustrate that automation and preparation to automate the mining environment is being carried out in Africa, and that this has potential for enhancing the health and safety of employees at the same time as maximising outputs for the mining industry. These two case examples are Syama Underground Gold Mine (SUGM) in Mali, which is currently transitioning to becoming a fully automated mine, and Sibanye-Stillwater (SSW) mining company's initiatives in South Africa. The chapter then presents a novel FBA that can be utilised in the transition period to the mining systems becoming fully automated. Using this smart feedback monitoring system (SFMS), it is observed that as the mining industry transitions to fully automated mining, fewer employees are exposed to hazardous occupational noise. The approach of this chapter is that automation of the mining machinery, transportation and processes occurs in levels, stages or phases which evolve each year in varying degrees leading towards full automation of the mining systems. The chapter ends by offering recommendations on the effects of the change and provides a way forward for HCPs within the African context.

Globally, the history of mining dates as far back as 40 000 BC (Coulson 2012). Evidence of mining activities was discovered long before human beings started to record history. Archaeological discoveries indicate that mining activities were present and mining technology across the world began with the use of stone or stone hammers and animal bone antlers (Coulson 2012). As the need to access more minerals increased globally, more sophisticated machinery and transportation was introduced to the mining sector (General Kinematics 2020). In South Africa, the mining sector dates as far back as the 19th century, with the first formal mining project having been recorded in 1852 (Kaplan 2011).

The South Africa mining industry is reported to be one of the largest, most diversified and longest-established sectors in Africa and is also at the frontline globally (Kaplan 2011). This industry employs over half a million people and is categorised as one of the top foreign exchange earners for the South African economy. The Minerals Council of South Africa (MCSA 2020) reports that approximately R24bn is contributed, in the form of taxes, by the South African mining industry to the country's fiscus. In countries like Mali, Ghana and Tanzania, Chuhan-Pole, Dabalen and Land (2017) report that mining contributes significantly to their economies as well, with extractive industries constituting two-thirds of Africa's exports. Despite this significant monetary contribution to the continent, mining remains one of the industries where basic human rights are not always observed. One of the areas with documented evidence of substandard practices in Africa and generally LMICs is OHS (Moyo et al. 2015). Occupational noise-induced hearing loss is one of the occupational health hazards that has remained highly prevalent in the mining industry, despite reported HCP implementation (Khoza-Shangase, Moroe & Edwards 2020; Moroe 2018).

7.2. Background

Occupational noise-induced hearing loss is a permanent SNHL caused by exposure to excessive levels of noise while an individual is performing tasks in a work environment (Azizi 2010). Thomas Barr discovered the medical disorder in 1886, when he made the association between noise exposure in boiler makers and hearing loss (Azizi 2010; Moroe 2018; Nair 2014). Fowler, in 1939, described the characteristic 4 kHz notch used to explain NIHL (Azizi 2010). In 1965, ONIHL was formally recognised in the UK as an occupational medical condition that could be compensated (Nair 2014). From that moment onwards, globally, industries that tend to have excessive noise such as construction, aviation and mining have received attention from their respective industry stakeholders with efforts to evaluate, monitor and manage the impact of noise on workers (Moroe 2018; Nelson et al. 2005).

Occupational noise-induced hearing loss has been recognised globally as the leading work-related disability; hence, several efforts have been made globally to ensure minimisation of this occupational health condition. Moroe (2020) argues that HCPs are an effective and evidence-based intervention to prevent the occurrence of ONIHL, and some HICs have reported success in managing ONIHL via HCPs. These HCPs are successful if all pillars of the programme are implemented, and these pillars include:

- engineering noise controls
- monitoring of periodic exposure to noise
- administrative controls
- use of personal hearing protection (PHP)
- audiometric evaluations
- education and training of employee as well as management
- keeping records of the medical history of employees (Khoza-Shangase et al. 2020).

Moroe et al. (2018) conducted a systematic review which revealed that HCPs in Africa are currently not yielding the expected outcomes of reducing the incidence of ONIHL among the mining workforce. One of the reasons cited for the failure of HCPs in this region is the lack of adherence to the hierarchy of controls which mandates that engineering controls are the first line of defence in HCPs, where elimination and or substitution is not possible (NIOSH 2016). Elimination of the hazard at its source of generation, through direct action or confinement of the source, has proved to be one of the best approaches (Bies, Hansen & Campbell 1996). However, in some industries, complete elimination is not possible; therefore, engineering controls are next in line.

Engineering controls or technology are implemented to reduce noise exposure to tolerable levels through actions or activities that involve any measures to reduce generated noise and or transmission of noise through the air or structure of the workplace (Bies et al. 1996). These actions include changing the workroom's layout and modifying operations and machinery at the workplace (Bies et al. 1996). Additional use of engineering methods such as foam-coated walls could be used to reduce reflections and hence increase the rate of diminishing. Furthermore, with distance added, this removes the operator away from the noise and not just removing the noise itself. In extreme cases, it does not matter how loud a machine is; if there is no one nearby to hear it, then there is no risk of ONIHL. Noise problems may be defined with respect to (1) the source – the origin of sound, (2) transmission path – media through which sound propagates (through air and solid materials) and (3) receiver – the exposed worker (Bies et al. 1996). This demonstrates the propagation of noise from machinery and transportation modes to mineworkers.

To effectively curb ONIHL among mineworkers in this context, there is a need to identify and find ways of mitigating noise from sources that produce the largest amount of noise. This has implications for improved designs and implementation of the machinery and transportation modes that minimise noise emission, thus decreasing the threat of ONIHL. In supporting this initiative, mining equipment manufacturers and researchers in South Africa are collaborating to design equipment that is more robust and effective. For instance, Burger et al. (2004) developed a low-noise blast hole drilling system to be used in efforts to minimise risks of ONIHL among mineworkers. This drilling system was designed with the aim of emitting low noise levels to protect workers from excessive noise exposure as well as reduce risk of injury because of vibrations. Gumede et al. (2014) demonstrated how purchasing 'quiet' equipment would result in a reduction in ONIHL in the South African mining industry. Furthermore, these authors emphasised that contributions of engineering noise controls are potentially a permanent solution towards eradicating ONIHL and that this is one of the pillars that requires less supervision of mineworkers for compliance to be achieved. Gumede et al.

(2014) also highlighted the complexities of implementing such a system. These authors raise a need for the formation of a task team which is inclusive of all the relevant stakeholders, as well as adherence of the stakeholders to the agreed-upon initiatives, with acknowledgement of economic constraints. These complexities were also highlighted by Moroe (2020), who stated that HCPs are CIs and are easily influenced by efficient engagement of all stakeholders. Moroe and Khoza-Shangase (2018) also stressed the importance of involving all stakeholders in the conceptualisation and implementation of HCPs, a gap that was identified within the South African context.

The efforts to obtain an effective solution to ONIHL in the mines using engineering controls has recently taken a new turn with a current paradigm shift to the 4IR. This revolution entails amalgamating advances in AI, robotics, the internet of things (IoT), the industrial internet of things (IIoT) and many other advances (refer to Appendix A for definitions of terms). Globally, there is a shift in the mining industry to that which involves the design of fully autonomous engineering noise controls in transportation and machinery and the development of smart mines (Sánchez & Hartlieb 2020). The South African mining industry, being on the frontiers in mining machinery and transportation in Africa, is also actively involved in this shift.

Globally, mining companies are rapidly transitioning to the latest automation and digitalisation approaches in their operations. For example, Rio Tinto's Iron Ore mines in Australia had 73 driverless trucks that are operated 1207 km away in a central control centre (Petty 2016). Petty (2016) reports that other machinery that is automated at Rio Tinto include automated drills, shovels, conveyors, trains and ships. This author states that the mine's implementation of the automated system has resulted in a productive and safer workplace environment. Moore (2020) also reports on Boliden, a Swedish mine operator, which has partnered with Ericsson (a cell phone company) to use a 5G network to build a fully autonomous gold mine. Barrick Gold Corporation also partnered with Cisco System to integrate Wi-Fi sensors in its mines (Black Livingston, Stanton & Nussbaum 2018). South Africa is also at the forefront of implementing autonomous mining systems that would result in smart mines. Randgold Resources and AngloGold Ashanti are currently using robotic loaders 0.8 km below the surface (Morton 2020). The main goal of implementing the automated system is to increase efficiency and improve the OHS of mineworkers. Morton (2020) also recognises the benefits of automation in its ability to increase efficiency and decrease expenditure while improving OHS. The benefits, however, come at a cost.

It is anticipated globally that with an increase in automation, there will be a reduction in the tax submitted to governments by mining companies (Deloitte 2018). According to Lovells (2018) and Cosbey et al. (2016), it is projected that some countries that host mining companies might experience a reduction in socio-economic benefits because of the implementation of the current new technologies. The income lost will be mainly from lost local jobs and personal income revenue. It is therefore important that governments have contingency measures in place for this eventuality, a discussion that is outside the scope of this chapter.

To fully understand how automated systems work and their role in eliminating ONIHL, a discussion on the evolution of mining machinery is presented in the next section. This evolution covers past, current and envisioned future trends of engineering controls of noise in mining. Considering that mining technology takes a very long time to change, the following timelines will be used for clarity: pre-1980s, current and post-20s.

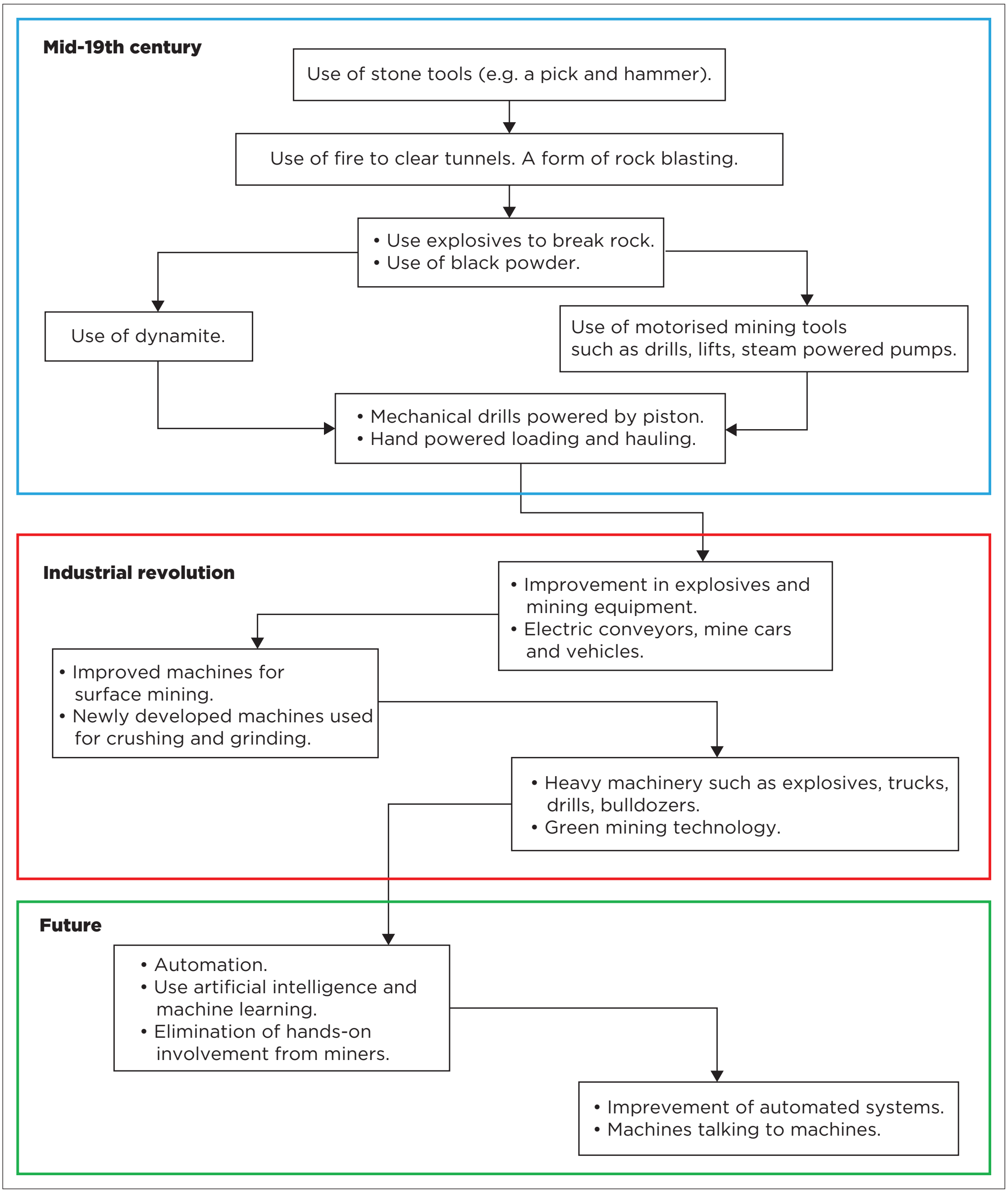
7.3. Evolution of mining machinery

7.3.1. Past trends in engineering mining machinery and transportation

Figure 7.1 shows an overview of the evolution of equipment and transport used in the mining industry globally over time. The era leading to the mid-19th century and the years before can be considered the history of mining. Figure 7.1 summarises the following timelines (Mining Technology 2018):

- 1500s – The original mine carts were developed and were used to move mined debris.
- 1900s – The continuous miners were introduced in the mining industry.
- 1912s – The Hoadley-Knight machine was developed for mining coal. It used an electric motor.
- 1934s – The first dump truck was developed. These were improved to monster dump trucks.
- 1978 – The Bagger 288 was designed and was the biggest land vehicle in the world.
- 1998 – The second-biggest dump truck for the model classic CAT797 was developed.
- 2008 – Automation of mining equipment and processes was initiated, for instance, Rio Tinto driverless cars.
- 2013 – The biggest dump truck was developed, and its sales began in 2014.
- 2017 – Electrification of mining machines or vehicles. Currently companies are working on developing trucks that are enabled with digital, AI and machine learning technologies.

This timeline depicts the progress made over time and the increase in the complexity of the mining machinery and transportation, thus mapping an increase in the amount of noise produced over this time period. This evidence of increasing noise from this equipment is documented by Babich and Bauer (2006) and Giardino, Bobick and Marraccini (1977), who conducted tests and took measurements of the different levels of noise emitted at different times.



Source: Created by Madahana M. (adapted from Ali & Frimpong 2020; Babich & Bauer 2006; Coulson 2012; General Kinematics 2020; Marklund 2017; NS Energy 2020; Ramdoo 2019).

FIGURE 7.1: Overview of the transportation modes and machinery used in mines over time.

Some of the past documented trends with this mining equipment show that the mining methods involved hands-on mining. The mineworkers had to use hand tools. Although these were not efficient in terms of the mining output, they did not produce excessive noise when compared to current equipment. In pre-1980s, most mineworkers depended on hearing protection to protect themselves from excessive noise (Kock 2013). Researchers also began to implement engineering controls, for instance, the use of barriers. The amount of noise that was emitted in this period was not excessive. An increase in demand for metals and minerals globally resulted in the mining industry designing and manufacturing more complex equipment to meet this demand.

7.3.2. Current trends in engineering mining machinery and transportation

The current period is characterised by heavy machinery and sophisticated transportation leading to excessive noise. There has been an upsurge in the number of ONIHL cases and lawsuits in this period. The greatest challenge of mining in the industrialisation period has been safety and occupational diseases that affect the mineworkers, thus reducing efficiency and productivity (NIOSH 1996; Stanton 2003).

The designing of bigger machines and introduction of superior and sophisticated transportation modes has resulted in an increase in efficiency and production output (Cascio & Montealegre 2016), while the amount of noise produced in the mines has also increased. At present, most mines operate between manual systems, electric systems and semi-automated systems (Marklund 2017). Most of the current machinery and transportation is sophisticated and designed to operate at optimal efficiency. Table 7.1 lists some of the mining machinery and the transportation modes used in the mines and the number of decibels produced by each machine (Babich & Bauer 2006; Giardino et al. 1977). These values are an estimate and vary substantially for different operations; however, what is common is that they all produce levels of noise hazardous to the human ear. The operating mode could be tram, cut, load, unload, bolt, drill or idle. It is important to note that dBA values being used in this Table to quantify loudness depend significantly on the position and distance of the measuring device, relative to the noise-making machine.

TABLE 7.1: Machinery and transportation in the mines and estimated noise levels.

Machinery and transportation	Average estimated noise levels (DBA)
Continuous miner	109
Loading machine	102
Shuttle car	92
Cutting machine	96
Coal drill	91
Roof bolter	103
Stoper	121
Long wall shear	95
Auxiliary fan	120
Miner or bolter	112

Key: DBA, A-weighted decibels.
Source: Babich & Bauer (2006; cf. Giardino et al. 1977).

While many of the values exceed acceptable human limits, they only exceed those limits if the human's ear was in the exact position where the noise was measured from. As one moves away from the machine, the noise level diminishes with distance, up to a point where an extremely loud machine can fall within hearing limits, if the operator is removed sufficiently far away from it.

Evidence suggests that the main sources of noise in the mines are the machinery operated, the mining activity involved and the mode of transportation utilised to carry the mining produce from one area to another (Sensogut 2007). O'Brien et al. (2006) argue that among the machinery used in mining, the rock drills, irrespective of whether pneumatic or hydraulic, have been observed to produce the greatest amount of noise. Operators of rock drills are therefore at an increased risk of developing ONIHL. According to O'Brien et al. (2006), in South Africa, there has been collaboration between the MHSC and research institutions such as the Council for Scientific and Industrial Research (CSIR) to improve the design of rock drills to reduce the amount of noise they emit.

For the past 10 years, the MHSC has sponsored several projects to research and develop methods to reduce noise emissions from machinery. Studies conducted incorporated the main noise generation features of the machinery and the conventional noise reduction techniques available. Noise generated by the machinery can be controlled directly or remotely from the source (Henson 1996). Controlling noise from the source might require extensive re-engineering of the machinery (Russell & May 1977). This exercise requires comprehensive working knowledge of the machinery, which is not easy to obtain because that knowledge (intellectual property) is held by the manufacturer. More researchers are involved in working on systems that can be used together with HCPs to minimise or eliminate excessive noise from the source (O'Brien et al. 2006). Considering the challenges that the mining industry is currently facing in terms of balancing the efficiency of the machines while protecting the workers, most mining companies have started to invest in the automation of their systems.

7.3.3. Future trends in mining

The future mining industry is envisioned to be devoid of anyone working underground or interacting with any machinery in an industry that employs transport modes or processes that are considered safe. Future trends and projections of the industry globally are for mineworkers to engage with underground and surface mining processes from surface control rooms.

Globally, the mining industry is slowly transitioning into being fully automated. There are currently levels of automation that have been implemented. To proceed to higher levels of automation, there are emerging and implementable technologies being identified for the automation of machinery and processes in the mines (Ramdoo 2019). Should these technologies be successfully implemented in all the mines in Africa, then a significant reduction in ONIHL cases will be observed. These technologies are normally amalgamated, resulting in hybrid systems that are efficient in catering for the safety of the mineworkers while protecting their health as well (Ramdoo 2019). A summary of some of the emerging technologies in the mining industry that will result in the reduction of ONIHL in the future are illustrated in Table 7.2. These technologies will ensure that activities lead to a reduction in mineworkers being exposed to occupational noise, given that the technology will replace the employee.

7.3.4. Automation in the mining industry

The authors of this chapter are following the approach that the modernisation of mining machinery (automation, robotics, AI, machine learning, IoT, digitalisation), transportation and processes are researched and implemented in levels, stages or phases – and not simultaneously. Modernisation in the mining industry is a dynamic process that evolves each year with different milestones being achieved, as described by Moore (2019). It is also important to note that automation may occur in varying degrees, as cited by Bołoz and Biały (2020). Automation may be divided into several phases, and the goal is to have a fully automated system, but the initial stages may not be fully automated. Regardless of what phase they are in, they still fall under the category of automation. The approach followed by Moore (2019) is described in the section that follows, where the percentages provided are not prescriptive but rather have been used to illustrate the shift towards fully automated systems.

Phase 1 (Hybrid):

- Automation may involve the use of systems with remote assistance, for example, using software for underground mine vehicle localisation (Moore 2019; Xu et al. 2017).
- This phase is 80% human-controlled, 20% automation.

Phase 2 (Hybrid):

- The automated system and mineworkers are both involved in controlling the system.
- The automated system takes control in certain specific situations. The targets are specified by the mine operator or mineworker, and they also keep a check on the state of operation.
- In this phase, the mineworkers are heavily in control of the process.
- This phase is 50% human-controlled, 50% automation.

TABLE 7.2: Technology and its role in reduction of ONIHL in the mines.

Role	Technology	Role it plays in reduction of ONIHL
Big data enablers	Sensor technology: Conversion of physical quantifiable numbers into electrical signals which are then transmitted to the controller	It may be used in autonomous vehicles, remote monitoring of equipment and infrastructure and predictive maintenance. This eliminates the need to send mineworkers to environments with excessive noise.
	Connected wearables: A device that permits interface between humans and machines	This may be used in PPE, for instance, hearing protection. This is significant because data can be collected daily, weekly or monthly from the hearing protection worn by the mineworkers. This information is instrumental in assisting in real-time monitoring of the hearing of mineworkers.
	Drones: Unmanned aerial vehicles (UAVs) that navigate autonomously without human intervention	May be used in mine inspection, monitoring and assessment of the drilling and blasting processes. Drones may also be deployed to survey the mining processes and provide reports on the mining activities producing excessive noise.
	GPS: Satellite-based navigation system	Heavy machinery, bucket-wheels and dozers need GPS to be controlled. Managing of the haul truck fleets, drill guidance, vehicle tracking and dispatch also need GPS.
Big data users	Machine learning: The usage of huge data sets, artificial neural networks and algorithms to identify patterns. Universal quantum computing may also be used	Can be used to estimate NIHL. It may also be used to make the machinery and transportation autonomous.
	Advanced analytics: Used to make data-driven decisions, it includes big data characterised by huge volumes of data from diverse forms and sources. This data is applied in real-time investigation and enables accurate decision-making	It may also be used for identification of behavioural patterns (descriptive), provision of recommendations on what to do (predictive) and grouping of people with common features (clustering). This is then used by the mining company in profiling new employees and checking those who are susceptible to ONIHL. With such analytics, equipment downtime is reduced.
	Automation	Automated machines, processes and transportation eliminate hands-on involvement; hence, mineworkers are not exposed to ONIHL. Certain occupations, for instance drill-rig operators, will be revolutionised. Automation introduces autonomous haulage, driverless mine cars and remote vehicle operation.
	Robotic process automation: Amalgamating AI and automation	Robots would possibly be used in doing manual work in the underground mine where mineworkers could have been exposed to occupational noise. The robots are capable of making human-like decisions and performing tasks efficiently.
	Software automation	Excavators are among the machines that produce excessive noise in mines. Software automation may be used in remote-controlled excavators.
	Digital twin: Virtual simulator of a mine	This technology would be significant in training mineworkers who were previously underground to learn how to perform the same tasks but from surface control rooms.
	Cloud computing	It will make information accessible from anywhere; hence, the surface control room of a mine can be located anywhere.
Big data trackers	Internet of Things and Industrial Internet of Things	Will be used to automate maintenance and operations of machine. This will result in transition from preventive to predictive maintenance.

Key: AI, artificial intelligence; GPS, global positioning system; NIHL, noise-induced hearing loss; ONIHL, occupational noise-induced hearing loss; PPE, personal protective equipment.
Source: Ramdoo (2019).

Phase 3 (Hybrid):

- This is a limited autonomy level where the automated system takes control under certain circumstances, and mineworkers or operators occasionally step in to keep track on what is happening to the system.
- For example, in underground mines, autonomous drilling which is followed by autonomous charging of explosives may be used.
- The remote operator may receive alerts in exceptional circumstances.
- This phase is 60% automation, 40% human-controlled.

Phase 4 (Hybrid):

- The system has an additional predictive aspect.
- System can learn from its past actions and resolve issues autonomously.
- In this stage, human operators are seldom involved.
- This phase is 80% automation, 20% human-controlled.

Phase 5 (Fully automated):

- The system is fully autonomous.
- In this stage, human beings are completely removed from the process.
- Human beings are not required in the actual mining process.
- For example, a self-driving electric mining vehicle may be used for full autonomous loading of the ore (Moore 2019).
- This level is currently aspirational, and most mining companies are working towards it.
- This phase is 100% automated, 0% human-controlled.

7.3.5. Automation of the mining machinery, transportation, drilling and blasting

The computer science field of AI involves altering and developing machines with the know-how to conduct various tasks without requiring specified instructions (Ali & Frimpong 2020). Ali and Frimpong (2020) claim that the main objective of incorporating AI in mining is to ensure that machines behave or conduct tasks with the intelligence of human beings. Machine and deep learning are specialised applications of AI which involve training machines in pattern recognition and precise extraction of information from preceding cases. Machine learning can be applied at any stage of the mining process, such as mine planning, production and during closure or reclamation (Ali & Frimpong 2020).

Wang and Siau (2019) assert that AI and machine learning innovatively induce smartness and intelligence in machines. Complex, risky and dangerous mining processes and operations can be automated using AI and machine learning (Ali & Frimpong 2020). Globally, it has been noted that the mining industry is behind other industries when it comes to the application of innovative methodologies that can result in operational efficiency and reduction of injuries or risks among mineworkers (Jacobs & Webber-Youngman 2017). Bellamy and Pravica (2011) reported that the advancement of machine and process automation with intelligent technology improvement in the mining industry has been extremely low, with Narendran and Weinelt (2017) affirming that the mining sector has lower levels of digitalisation when compared to other industries. Nevertheless, the mining industry is starting to identify and comprehend the significance of using advanced technology and automation and has begun to discover the practical implementation of fully automated mines (Sánchez & Hartlieb 2020). It is expected that this trend will change in the near future, particularly with some research beginning to explore the field of AI and machine learning to improve the current technologies in the mines (Noone 2020). With the implementation of smart, automated systems, the machinery can self-navigate, sense the environment and communicate with other machines in the underground environment (Noone 2020).

When such systems are implemented, mineworkers, especially those working as haulage drivers or drill-rig operators, will have to be retrained. They will be mainly based in the surface control room, removing them from hazardous noise sources. The mineworkers only interact with the underground mining environment from the screen of their computers and hence are not exposed to occupational noise at all. The more a mine is automated, the less the mineworkers interact with noise that is above the legislated level. This results in a reduction in incidents of ONIHL in the mines, thus the importance of research into AI and automation. Evidence relating to recent advances in studies geared towards the use of AI and automation of machinery, transportation, drilling and blasting in the mines is increasing.

7.3.6. Research in the automation of machinery and transportation

For underground mining, Roberts et al. (2000) document the development and implementation of a load–haul–dump (LHD) machine which is capable of navigating through the mine autonomously by sensing the walls of the mine tunnel. Sukkarieh, Nebot and Durrant-Whyte (1999) and Nebot (2007) document a commercial implementation of free-range, autonomous straddle carriers. Both systems are fully autonomous and operate in environments that are without any manual operations. Improvements still have to be done to ensure that these machines comprehend their environment and have the capability to make smart decisions based on the changing environment. These machines should also be able to recognise other machines and interact with other equipment within the underground mine (Nebot 2007; Sukkarieh et al. 1999). With these types of autonomous machines being used for underground mining, mineworkers will not be exposed to occupational noise.

Surface mining has excavation processes that use haul trucks which significantly contribute towards increasing levels of noise within the mine. Because surface mines contribute a significant share in mineral production (Awuah-Offei & Rehman 2018), it is important that automation be included in surface mining to ensure safety, efficiency and reduction in excessive noise emission leading to ONIHL. Currently, the three main manufacturers of haul trucks, namely Komatsu, Caterpillar and Hitachi, have collaborated with mining companies in this area (Parreira 2013). For instance, Broken Hill Propriety Company Ltd (BHP) has developed and implemented automation technology in real mining environments (Parreira 2013). Parreira (2013) argues that an improvement to this technology will be observed as real-time smart computational fields evolve and are effectively included in the digitalisation of mines.

When mineworkers are deployed to the surface control rooms, they no longer interact with the underground mining environment that has excessive noise. The previously performed functions must be autonomously performed by machines (Nebot 2007; Sukkarieh et al. 1999). Inclusion of AI that is smart enough to mimic a real mineworker can be quite challenging and requires time (Parreira 2013). This is because the activities performed by mineworkers were not just formal tasks; they required the worker to have a broader state of awareness. Therefore, the automated machines must be improved to a stage where they can detect the actual state of the mining setting during machine operation, irrespective of environmental conditions.

Researchers, manufacturers and the mining industry still have a long way to go in terms of updating the existing autonomous models and improving the current performance algorithms to ensure that the machines and transportation utilised are efficient in automated real-world haulage operations. Manufacturers involved in the development of autonomous technology for haul trucks are yet to include AI and machine learning in their technology (Ali & Frimpong 2020). Ali and Frimpong (2020) highlight that the current algorithms can be altered to develop frameworks that would result in intelligence and smartness in haulage trucks. Smart haulage trucks will therefore be capable of considering the various states of their path, interacting and communicating intelligently with other equipment in the mine and optimising the usage of the truck. With such levels of smartness in the machines, there will no longer be a need for truck drivers to go underground, thus removing exposure to occupational noise and the risk of developing ONIHL.

Other machines that researchers and mining companies are working towards full automation on are material excavation and earth moving equipment (Bradley & Seward 1998). Material excavation and earth moving usually generates significant noise because these involve vigorous intricate contact between the ground and the excavator. Bradley and Seward (1998) provide the main performance criteria for autonomous excavation. One of the criteria is that it should be able to manoeuvre with the average speed of an operator in any state. Should the currently designed machines satisfy and exceed the criteria set by the mining industry, then there will be no need for a human operator and thus a reduction of mineworkers' exposure to hazardous occupational noise.

Efforts are still being made to improve and develop automatic excavators. For instance, Bullock and Oppenheim (1989) designed a system that is sensor-based for automating the backhoe excavation process. Gocho et al. (1992) developed an automated wheel loader for shared processes, while Huang and Bernold (1993) presented a technologically advanced idea of rock and utility lines recognition in automated control of the backhoe. Shi, Lever and Wang (1996) presented the automation of the excavation processes using the neural network and fuzzy logic approach. Researchers are currently working on automating the drag line, with evidence of the development of a semi-autonomous drag line documented (Corke, Winstanley & Roberts 1997; Roberts et al. 2000; Winstanley, Corke & Roberts 1999). A dragline is another machine utilised in the mines that emits high levels of noise. It is the preferred excavation tool for surface mining because of its cost and efficiency (Wei, Cai & Chen 2007).

Other advances towards automating the drag line for noise reduction and or exposure include:

1. the use of Bayes classification models and neural network for object recognition (Chi & Caldas 2011)
2. the application of a system that is vision-based for hydraulic excavators and trucks (Ji et al. 2017)
3. photogrammetry algorithm video analysis techniques (Bügler et al. 2017)
4. advancements to the vision-based model for sensing the dragline bucket pose pioneered by Hainsworth (1996)
5. use of a novel approach for sensing the dump truck and its loading cycles through an operation using a pattern-recognition-based system (Dalal & Triggs 2005)
6. use of a histogram of oriented gradients (HOG) model in amalgamation with the support-vector machine (SVM) algorithm for designing equipment, that is, excavator and dump truck (Golparvar-Fard, Peña-Mora & Savarese 2015; Memarzadeh, Golparvar-Fard & Niebles 2013).

The most current advancement in dragline automation was performed by Somua-Gyimah et al. (2019) using deep learning methodology with convolutional neural networks (CNNs) for terrain recognition and object detection in duties involving mining excavation. All these advancements have significant implications for the OHS of miners and particularly exposure to excessive noise.

7.3.7. Automation of the drilling and blasting process

The process of drilling and blasting results in excessive noise being produced (Nebot 2007; Sukkarieh et al. 1999). Drill operators are among the most exposed to hazardous noise levels and therefore have some of the highest reported cases of ONIHL (Musiba 2015; Ntlhakana, Kanji & Khoza-Shangase 2015). Consequently, the authors of this chapter argue that automation of the drilling and blasting process is the main technological advancement that will contribute to the reduction of incidences of ONIHL among drill operators in mines. Numerous efforts are documented which have the goal of automation in this process. Thompson (1999) and Girmscheid and Wälti (2001) provide documentation on the automation of drilling and blasting activities on the surface. Ahamed et al. (2016), Hashmi, Graham and Mills (2000) and Pendokhare and Quazi (2012) document the use of fuzzy-based controllers, thus introducing intelligent drilling systems in the mining industry. Irrespective of this evidence, there is still a need to develop intelligent drilling systems. Such systems are autonomous and have AI, meaning that the machines can make smart decisions based on the changing environment, without the involvement of a human. This is a fully automated drilling, loading and haulage mining environment.

Within the African context, there is already an existing fully automated mine in SUGM, Mali (NS Energy n.d). The government, research institutions and the mining industry in South Africa are collaborating to explore ways to introduce automation and digitalisation in South African mines (Ali & Frimpong 2020). In the automation period, the main objective is to eliminate the involvement of humans by using autonomous machines and transport modes. The implementation of a fully automated mine in Africa gives African countries and other LMICs a case study of what is possible and the challenges involved in the process.

7.3.8. Syama Underground Gold Mine in Mali

Syama Underground Gold Mine is both an open cast and underground mine that is located 300 km from Mali’s capital city, Bamako (NS Energy n.d.). This mine, originally developed as an open cast mine by BHP in 1980 (NS energy n.d), was transferred to Randgold Resources and finally to Resolute Mining in 2004. Subsequently, Resolute Mining collaborated with Sandvik to design a functional, fully automated and digitalised underground mine (Alan 2019). The new technologies implemented by Sandvik at this mine, tested in other places in the world, have fully automated drilling, loading and haulage capabilities (Cloete 2019). This implies significant headway in minimising hazardous and excessive noise emission in processes that are the greatest sources of noise in mines and the largest contributors to ONIHL.

The 1500 miners at SUGM work under very different conditions (see Figure 7.2 and Figure 7.3) in comparison to their counterparts in a mine that is not automated. The dress code is usually office wear and there is no need for heavy PPE, which includes HPDs, heavy hobnail boots, oxygen tanks and overalls (Balch 2019). The SUGM is equipped with fully automated drilling (robotic drill operators), haulage (driverless trucks) and loading (see Figure 7.4). The mine operates for 24 h, 7 days a week and it is reported to be 30% more efficient (Alan 2019). Because of the full automation, ONIHL is not a concern in this mine.

Source: Photograph provided by the Syama Underground Gold Mine. Published with appropriate permissions provided by the Syama Underground Gold Mine.

FIGURE 7.2: Mineworkers in an underground surface automation control room at the Syama Underground Gold Mine.

Source: Photograph provided by the Syama Underground Gold Mine. Published with appropriate permissions provided by the Syama Underground Gold Mine.

FIGURE 7.3: Mineworkers in an underground surface automation control room at the Syama Underground Gold Mine.

Source: Photograph provided by the Syama Underground Gold Mine. Published with appropriate permissions provided by the Syama Underground Gold Mine.

FIGURE 7.4: An automated truck at Syama Underground Gold Mine.

7.3.9. Sibanye-Stillwater

Sibanye-Stillwater is a South African gold mining company that is at the forefront of innovation and digitalisation in the mining sector (Pretorius & Mativenga 2019). Its main objective is to make the mining environment safer, more efficient and more sustainable in the future. Mining Review Africa (2019a) reports that this precious metal mining company, although managing some of the oldest gold mines in South Africa, believes in the utilisation of digital technology in its mining endeavours. The reasoning behind this approach is that, when implemented effectively, technology has the potential to enhance operational efficiencies with lower costs. This then enables the mining company to lengthen the life of some operations by adapting more of its resources to economically extractable reserves for the attainment of larger value from its assets (Mining Review Africa 2019a). Sibanye-Stillwater works together with experts from various institutions and industries to develop cutting-edge technology that will accelerate the implementation of automation and digitalisation in South African mines. Fenn (cited in Mining Review Africa 2019b) asserts that:

> Digital technologies allow us to focus the right human and financial resources, on the right task, at the right time. In every respect, it allows us to yield maximum value from deployed resources in a safe and sustainable manner. (n.p.)

Mining Review Africa (2020) highlights that spiralling labour and energy costs are also placing pressure on the financial performance of South African gold mines, thus making adoption of digital technologies and automation the wise options to explore and implement, with the coronavirus disease 2019 (COVID-19) pandemic having added to this pressure for automation (Mabena 2020). Because most of these new technological solutions rely on automation, supported by the merging of multiple technologies from AI to robotics, collaboration with research institutes is important.

Mandela Mining Precinct and Digi Mine Laboratory, both based at the University of the Witwatersrand in South Africa, are some of the research institutes that SSW is collaborating with to this end. The Mandela Mining Precinct is involved in coordinating research activities geared towards the revitalisation of South African mining operations by developing next-generation mining systems (Cloete 2020; Pelders, Nelson & Magweregwede 2019). Digi Mine Laboratory is part of the University of the Witwatersrand's Mining Institute, with a state-of-the-art mining laboratory that has a simulated mine used to mimic actual underground mining environments (Kwiri 2018). This is significant for researchers from across the continent who need to develop and test digital systems in a simulated environment. The main objective of the laboratory is to attempt to transfer surface digital technologies to the underground mining setting. Digital technologies therefore play a significant role in this collaboration. Despite the advances in automation research and pilot plants, the mining industry will have to transition into the automation stage. This will require the development of systems to provide a smooth transition. The following section proposes such a model for the African mining industry.

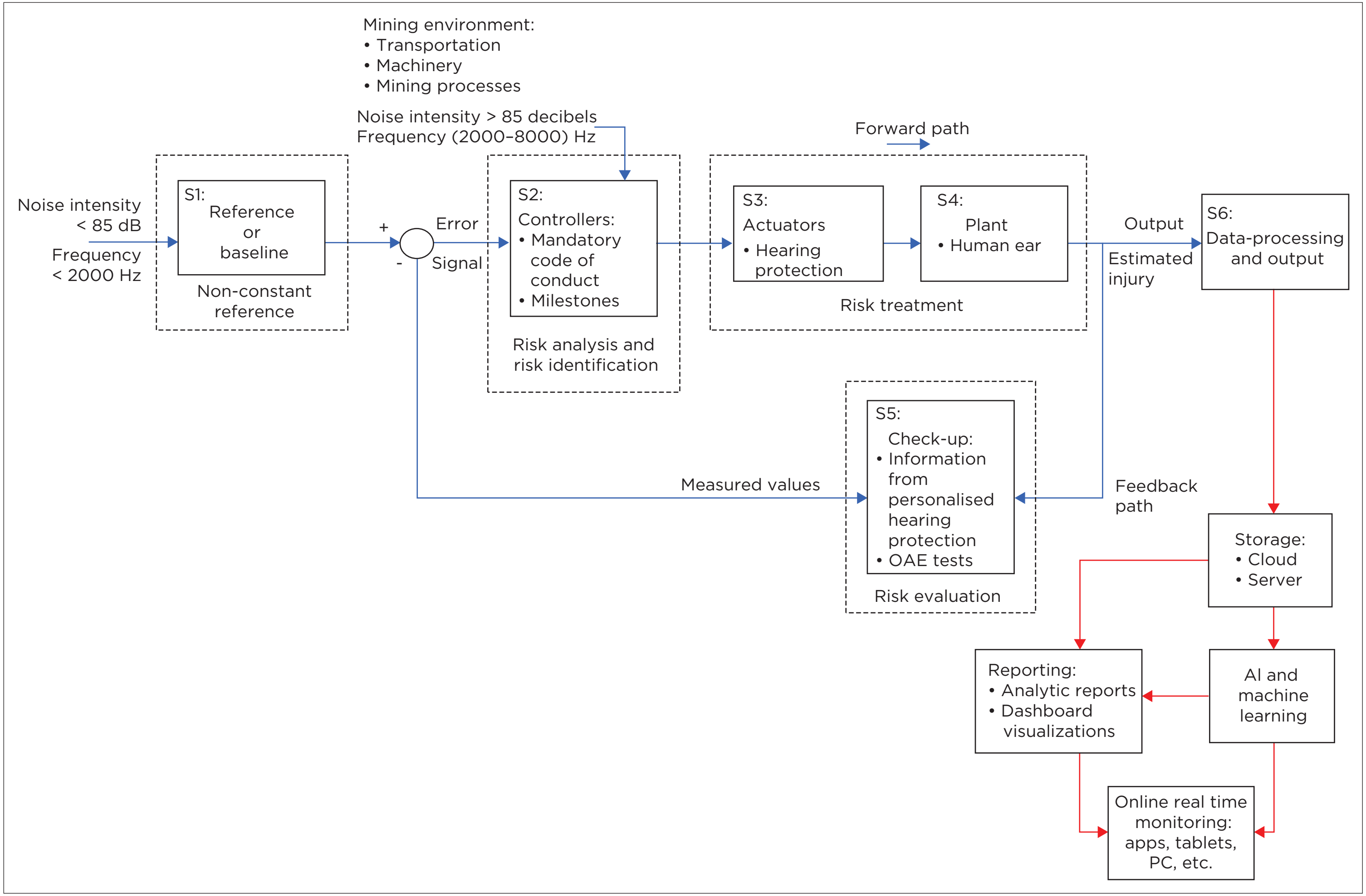
7.4. Solutions and recommendations

The African mining industry is currently undergoing a transition period. This implies that the mining industry is shifting into technologically advanced, state-of-the-art, fully automated mines. The transition period may take a short or a very long time to reach the ideal fully automated and digitalised phase. Moroe et al. (2019, 2020) developed and tested a feedback noise-monitoring system, further improved by Madahana et al. (2019a, 2019c), Madahana, Ekoru and Nyandoro (2019b). The proposed SFMS presented in this chapter is an improvement on the two previously published systems. This proposed system can be used to monitor ONIHL while the mines slowly transition into automation. An additional subsystem of advanced analytics is added to the current SFMS. The system is further refined to eliminate hands-on experience, thus showing how it can still be repurposed and used to monitor the state of health of the machinery, without the worker being exposed to excessive noise. The machines play the role of a mineworker, and hence, for the mine to remain efficient, there must be constant monitoring of the health of the autonomous machines used. Figures 7.5, 7.6 and 7.7 provide diagram overviews of how the state of health of a machine in a fully autonomous mine can be assessed using the SFMS. It is important for machine monitoring systems to be availed in anticipation of the required maintenance and servicing of the equipment. This will ensure that there is no regression at any point to semi-automated or manual systems that predispose mineworkers to ONIHL.

The following definitions are used in the explanation of the different subsystems of the SFMS in Figure 7.5:

- Definition 1: Transmission refers to the media through which sound propagates. Transmission in the mines mainly occurs through the air and the solid materials (Hansen 1996).
- Definition 2: Receiver represents the exposed worker (Hansen 1996).
- Definition 3: Sources represents the origin of sound (Hansen 1996).

Figure 7.5 shows an improved version of the model in Moroe et al. (2019, 2020) and Madahana et al. (2019a, 2019b, 2019c) publications. The modified Figure includes the automation block with the reporting subsystem. The functions of the subsystems are explained in Table 7.3. In the automation phase, inclusion of data-driven decision-making is critical. The dashboards play a significant role in gaining quick insight into features of the information obtained from the mine. Early intervention strategies requiring urgent attention are then implemented using real-time insights obtained from the dashboards.



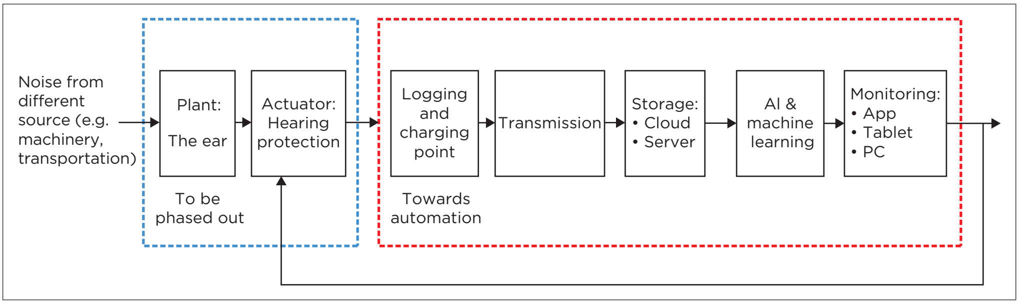
Key: AI, artificial intelligence; OAE, otoacoustic emission; PC, personal computer.
Source: Author's own work.

FIGURE 7.5: Smart feedback noise monitoring system (comprehensive).

TABLE 7.3: Subsystems and their functions.

Subsystem	Function
S1: Reference or Baseline	Represents an individual who has not been affected by occupational noise, The individual only experiences presbycusis.
S2: Controller	Represents the Mandatory code of conduct and milestones set by the MHSC to ensure zero harm to mineworkers.
S3: Actuator	Hearing protection worn by mineworkers, for example, customised ear plugs.
S4: Plant	Represents the human ear. The human ear also represents the exposed mineworker who acts as a receiver.
S5: Check-up	This subsystem represents the ear check-up for the mineworker. It could be a rapid test, for instance, otoacoustic emissions tests. Annual hearing check-ups also fall in this category.
S6: Data processing and output unit	Information obtained from this system is processed and used for data-driven decisions in the mines.
Storage	The information could be stored in the cloud or on servers.
Reporting	Reports and dashboards can be created from this information.
Online real-time monitoring	This subsystem is critical for monitoring of the mineworkers and provision of early intervention.

Key: MHSC, South African Mine Health and Safety Council.
Source: Authors' own work.

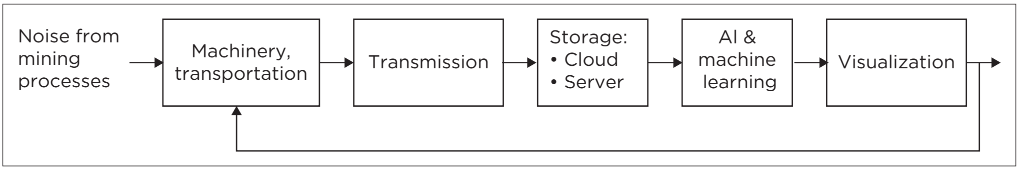


Key: AI, artificial intelligence; App, application; PC, personal computer.
Source: The figure illustrates modification of the work done in Madahana et al. (2019a, 2019b, 2019c). The manual aspects to be phased out have been identified and the subsystems to be used in automation have also been identified.

FIGURE 7.6: Smart feedback noise-monitoring system (summarised).

Figure 7.6 provides a summarised version of Figure 7.5. The logging and charging point subsystem is used to charge the hearing devices while at the same time information is transmitted to the storage facility which could be server or cloud-based. The AI approach is applied to the collected data and used to predict mineworker patterns. For example, the mineworkers could be clustered and classified and recommendations provided to each cluster. Artificial intelligence can be used to monitor individual mineworkers and provide customised behavioural change recommendations to them that ensure preservation of hearing.

The state of health of a machine can be determined by the sounds it produces at various stages of operation. Automatic fault diagnosis and intervention can be performed early to ensure the machines are serviced and repaired before they completely breakdown (Rodríguez et al. 2014). Figure 7.7



Key: AI, artificial intelligence.
Source: The figure illustrates an original conceptualisation by M. Madahana of how the smart feedback-based system will evolve in future to allow for the machinery and transportation modes to be monitored. The Figure was inspired by considering some aspects from Molaei et al. (2020) and Rodríguez et al. (2014).
FIGURE 7.7: Mining machinery and transportation smart feedback 'state of health' monitoring system.

shows a block diagram of how machines can be monitored from the surface control room of the mine daily. When mining machinery is faulty, a robot can be deployed underground on an autonomous vehicle to carry out repairs; thus, mineworkers do not have to go underground. The IoT is extensively used in this subsystem.

■ 7.5. Conclusion

With the paradigm shift towards automation in the mines, there are speculations and promises regarding what the new technology can or cannot do. Transitioning to fully autonomous mines will be phased in gradually in African mines. All stakeholders in the mining industry, including the African governments, political parties, communities and mineworkers, will have to be convinced of the likely impacts of automation and digitalisation and whether these will be positive or negative. Some of the questions that are likely to be asked by stakeholders during this transition are:

- Are fully autonomous mines viable and sustainable in Africa (or a specific African country)?
- Within which reasonable timeframes will this change be implemented and start to pay off?
- How will these changes affect the labour market in the African mining industry?
- How will these changes impact the environment?
- Will this automation bring an improvement in safety and reduction in occupational diseases and conditions, such as ONIHL?

Automation has commenced in some African countries and in some South African mining sectors, such as the diamond, coal and copper extraction sectors. A variety of automated machines using software are currently being tested to improve safety and efficiency. In South Africa, MHSC, together with researchers, mining equipment manufacturing companies and mining companies, are working collaboratively to bring about automation and digitalisation at a faster pace in more sectors than currently available. Although African countries still have a long way to go before real-time information management systems, robotic technologies and IoT become the standard way of operating mines, the proposed unique monitoring system can be used in the transition period to ensure a smooth transition to fully automated mining within each country in the continent. This will significantly impact the elimination of ONIHL as an occupational health condition in this sector.

Appendix A

Definitions of terminology

- **Automation:** Entails the development and implementation of technologies that result in the production of goods and services with minimum human effort. Automation may or may not be based on AI. The objective of implementing automation techniques and technologies in the mines is to ensure an improvement in efficiency, reliability, safety and speed of various tasks that were previously performed by mineworkers. Automation is also used in the mining industry to relieve mineworkers from processes that could pose health risks to them, and machines are used to perform those tasks. In the context of the mining industry, automation is a long-term process which is being implemented in levels, stages or phases. Automation may be subdivided into process and software automation and the application of robotic technology to mining vehicles and equipment (Moore 2019).
- **Mechanisation**: The reduction of human effort (manual work) in mining activities by introduction of machines and processes to assist.
- **Remote control:** Control of a machine or apparatus from a distance or remote location by means of radio or infrared signals transmitted from a device, for example, a fleet of driverless cars in Rio Tinto or a remote-controlled load–haul–dump (LHD) truck (Gustafson 2011; Sekar et al**.** 2019).
- **Digitalisation**: Digitalisation in mining refers to the application of computerised or digital devices or systems with the main goal of reducing costs, improving business productivity and mitigating health risks, thus transforming mining practices (Barnewold & Lottermoser 2020), for example, development of rock-cutting techniques via digitalisation of technical equipment by Anglo American in South Africa (Geschwindt 2021).
- **Artificial intelligence and machine learning:** Artificial intelligence may be defined as a method that permits the development of human-like cognitive capabilities to be used in automation of processes and tasks. Machine learning (ML) may be viewed as a subcategory of AI, and it involves application of pattern recognition techniques using historical data. An example is use of historical data together with ML techniques for reduction of back breaks and fly rock in blasting operations (Amini et al. 2012; Geschwindt 2021; Khandelwal & Monjezi 2013). Machine learning is also

used in recognition of damages in a mine and checking the state of health of equipment for reduction of unplanned downtimes and to avoid fatal break downs (Geschwindt 2021; Willingham & Marchant 2016).

- **Robotics**: Automation and robotics are both methods used to decouple mineworkers from technical machinery and transportation. Robotics entails research, design, development and implementation of robots or machines that replace human effort. Automation is the operation of the machine without human control (Barnewold & Lottermoser 2020).
- **Internet of things (IoT):** A technique that involves interconnection of physical objects that can communicate their status via Internet and be remotely controlled from anywhere.
- **Fourth Industrial Revolution (4IR):** Technologies that combine the physical, digital and biological domain. These technological developments will change certain aspects of human living and working. These technologies are also integrated in industry and manufacturing practices, for example, in the mining industry. Some of these technologies are AI, IoT, robotics, virtual reality, mobile devices, 3D printing, smart sensors, big data or analytics, augmented reality (AR), data visualisation, cognitive computing, location detection, nanotechnology, biotechnology, block chain, quantum computing and cloud computing. The effect of these technologies is normally viewed as to have ‘disrupted’ the currently existing practices of production or management (Humphreys 2020).

Section C

Complexities of HCPs in Africa

Chapter 8

Hearing conservation programmes in the context of occupational health and safety in Africa

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8.1. Introduction

Because of poorly implemented OHS regulations, reportedly, there are over 2 million occupation-related accidents with approximately 6 000 deaths globally (International Labour Organization 2014; Liu et al. 2020). These accidents also carry a significant cost to the employer and the economy. For example, in 2014 alone, the costs because of nonfatal occupational accidents approximated 4% of the world's GDP (Liu et al. 2020). In LMICs, the prevalence of work-related accidents is highest, while it is reportedly declining in HICs (Abdallah et al. 2020). Efforts to curb and or eliminate these accidents through OHS initiatives are heavily influenced by social, political and economic changes, in both negative and positive ways (Abdallah et al. 2020).

Excessive noise exposure is the most common and most neglected occupational risk and its control via HCPs is not routinely nor successfully

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implemented, especially in Africa (Moroe et al. 2018). This chapter positions HCPs within the context of OHS, using some African countries, such as South Africa, Zimbabwe, Ghana and Tanzania as key case studies, and it seeks to highlight the importance of effective OHS regulations within this context. The chapter does this by firstly presenting an overview of the impact of failure to implement OHS regulations. This is then followed by a discussion on OHS in LMICs, with a heightened focus on the African context. Furthermore, the contribution of apartheid in the implementation of OHS in the mining sector, for example, in South Africa (Abdallah et al. 2020) is deliberated on. The chapter then concludes by discussing the current status of HCPs in relation to OHS in the African mining industry. Although only a few African countries are used as case examples, because of the available evidence from those countries, the rest of the continent can utilise the evidence presented in this chapter and contextualise it to their countries as well.

The source of most catastrophic accidents in the workplace is attributable to the absence or weak implementation of OHS management systems (Liu et al. 2020, p. 692; Takala et al. 2014). Despite a sound knowledge of the OHS concepts globally, various industries continue to account for huge losses and inefficiencies because of job-related illnesses and injuries (Liu et al. 2020). Occupational health and safety is defined as (Alli 2008):

> [*T*]he science of the anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment. (p. vii)

According to Alli (2008), OHS is affected by sociodemographic changes, geographical factors, population movements and the consequent demands on the global environment. It is, therefore, understandable that employee protection against sickness, disease and injury associated with the working environment is an expected high-priority key performance indicator of all industries. As such, the individual, societal and economic costs of occupational accidents and major industrial disasters have long been a cause for concern from the individual level to the national and international levels (Alli 2008). This is particularly the case in LMICs (Abdallah et al. 2020).

In 2014, the ISSA estimated the costs because of nonfatal occupational accidents to be approximately 4% of the world's GDP annually. Arguably, all occupations have some risk for injury; however, the impact of risk varies across occupations, geographic locations and individual susceptibility (Abdalla et al. 2017). Geographically, LMICs report the highest work-related accidents, while the incidence is reportedly declining in HICs (Abdalla et al. 2017; Liu et al. 2020; Takala et al. 2014). According to Ncube and Kanda (2018) and LaDou (2003) 20% to 50% of the workforce in HICs has access to OHS services, while workers in LMICs have between 5% and 10% access, with Tanzania having less than 5%. A case study conducted by Moyo et al. (2015) on OHS legislation in

Southern Africa – South Africa, Zimbabwe, Botswana and Zambia specifically – revealed fragmented OHS laws in the government departments. On the other hand, Chau et al. (2014) and Leigh and Marcin (2012) opine that the decline in HICs could be partly as a result of the export of labour-intensive, hazardous industrial production. This export is usually to regions, often LMICs, where lower remuneration, relaxed and flexible workplace regulations and unsafe working conditions exist. Furthermore, while informal sector jobs are on the rise in these countries, the industries that provide these jobs do not routinely adhere to the OHS regulations, nor do they enforce or disclosed risks for accidents and injury (Abdallah et al. 2020). As such, while the true burden of occupational injury in these HICs is unknown, in the European Union approximately 6.9 million worker injuries were reported to have occurred in 2006 and 8.5 million in the USA in 2007 (Chau et al. 2014; Leigh & Marcin 2012). Although these figures may be outdated, they paint a picture of the magnitude of OHS requirements in the workplace. In LMICs, occupational injuries and fatalities are much more pronounced because, over and above the adopted imported hazardous jobs from HICs, the majority are employed in the informal sector or in accident-prone sectors such as agriculture, construction, fishing and mining (Abdalla et al. 2017).

Poorly implemented OHS regulations impact workers' performance and productivity. Therefore, improving the conditions for better health and safety has extensive implications for all stakeholders (employees, employers and economies) globally (Abdalla et al. 2017). Improving health and safety is important for employees' positive health and performance outcomes. This speaks to providing OHS systems or a supportive and healthy environment for employees, as well as providing education and training for employees to improve their health and safety knowledge (Liu et al. 2020).

Internationally, the most common occupational hazards have been reported to include (1) biological, (2) chemical, (3) physical and (4) psychological hazards (Government of Alberta 2011). Similarly, these hazards are prevalent in sub-Saharan Africa. However, as a result of the fragmented OHS regulations in some African countries, there is a lack of legislation relating to physical risk such as noise, vibration, light and ergonomics risks (Moyo et al. 2015). This is more so in the mining industry. As such, other health conditions such as HIV and AIDS take centre stage at the expense of these other significant hazards (Khoza-Shangase 2020a; Moyo et al. 2015). South Africa is faced with an increased burden of diseases such as HIV, AIDS and tuberculosis, with the highest prevalence and incidence in the mining sector (Khoza-Shangase 2020a, 2020b; Stuckler et al. 2013). Consequently, even OHS regulations tend to have a focus on these health conditions over ONIHL. Exposure to excessive noise is one of the common hazards in occupational settings; however, it is the most neglected occupational hazard, receiving the least attention. As far as lack of noise control through HCPs is concerned, Suter (n.d.) argues that noise is often perceived as a 'necessary evil', a part of doing business and an inevitable part of an industrial job. This author was alluding to the fact that compared to safety concerns, exposure to excessive noise causes no visible bloodshed, breaks no bones, produces no strange-looking tissue, and with enough exposure, workers get used to it. When workers 'get used to noise', they are not aware of the insidious nature of NIHL. Noise-induced hearing loss creeps up gradually over the months and years, mostly unnoticed until it reaches disabling proportions.

Noise is an unpleasant sound with physical and psychological effects on individuals exposed to it (Bolaji et al. 2018; Wang et al. 2020). Therefore, its presence in the workplace causes discomfort, stress and fatigue. This makes communication hard for workers, thus resulting in accidents as a result of compromised verbal communication (Wang et al. 2020). As far as human performance in the workplace is concerned, noise levels have been listed among the many performance-influencing factors such as the nature, complexity and context of the job and improper working conditions. Improper working conditions include poor ventilation, light, humidity, dust level and air quality. However, of these performance-influencing factors, noise is considered the most difficult to address because of its subjective phenomenon (Meerding et al. 2005; Parsons 2000).

Although noise is a global occupational health concern, it is more prevalent in LMICs and even worse in underdeveloped countries where efforts to curb noise are minimal (Wang et al. 2020). Statistics on the incidence of occupational noise in LMICs are not easily available, but evidence shows that the standard levels of noise exceed the occupational threshold stipulated in many HICs (Fuente & Hickson 2011; Themann & Masterson 2019; Wang et al. 2020). For instance, in South Africa, over 72% of the miners are exposed to noise levels surpassing the permissible level (Edwards & Kritzinger 2012). In Ghana, in a study conducted by Gyamfi et al. (2016) on workers at a quarry, findings revealed that all the machines emitted noise levels exceeding the minimum threshold, with levels ranging from 85.5 dBA to 102.7 dBA, and over 44% of the participants had a hearing loss. Similarly, Chadambuka, Mususa and Muteti (2013) found that mineworkers in Zimbabwe were exposed to excessive noise levels as plant processing had noise levels at 94 dBA, underground mining at 102 dBA and underground workshop at 103 dBA. Furthermore, 36.7% of the workers in this context had NIHL. A study conducted in Malawi's heavy and light industries revealed that noise levels ranged from 75 dBA to 102 dBA and that many industries are not complying with the national laws on noise in workplaces, and 13% of the workforce has a hearing loss (Chirwa et al. 2019).

Thus, with industrialisation in the context of absent HCPs, these higher average noise levels in LMICs are more harmful (Ali 2011). Moroe (2020) argues that this harm can be eliminated and or minimised through implementation of HCPs, adopting the complex intervention approach. Hearing conservation programmes are implemented in line with the hierarchy of noise control where engineering controls take precedence, with the use of PPE being last in the hierarchy (NIOSH 2016). Hearing conservation programmes have the betterment of health, improvement in quality of life, creation of a safe workplace and consequently a more effective workplace (Wang et al. 2020) as some of the benefits that are much-needed within LMICs' working environments.

8.2. Occupational health and safety in low- and middle-income countries

Liu et al. (2020) report that in LMICs OHS policies are implemented; however, the enforcement capacity of these regulations appears to be weak. For instance, in Ghana, according to Annan, Addai and Tulashie (2015), there are two legislations that provide guidance for the implementation of OHS regulations: (1) the *Factories, Offices and Shops Act 1970* (Act 328) and (2) the *Mining Regulations 1970* LI 665. Activities related to the mining sector such as performance of accident investigations, implementation of safety guidelines, auditing and inspection and evaluation of existing controls are under the purview of the Inspectorate Division of the Minerals Commission in the mining industry. The Ghana Chamber of Mines and the Inspectorate Division of the Minerals Commission have a technical committee comprising representatives from all the registered mining companies (Annan et al. 2015). Despite the enacted Mining Regulation 1970 LI 665, there are no comprehensive national OHS policies in Ghana (Annan et al. 2015). Reportedly, the legal provisions on OHS in Ghana have a limited scope and some critical industries such as agriculture and the majority of the informal sectors are not included in the aforementioned Regulations (Annan et al. 2015).

Other entities related to OHS include the *Workmen's Compensation Law 1987*, the *Environmental Protection Agency Act 490 of 1994* and the *Ghana Health Service and Teaching Hospitals Act 526 of 1999* (Annan et al. 2015). However, Annan et al. (2015) argue that these entities will benefit from renovative overhauls to be on par with international requirements and standards. In 2007, the Ministry of Health also identified the following in the implementation of OHS regulations: (1) frail OHS infrastructures, (2) incompetent OHS professionals and (3) poor monitoring and surveillance for OHS diseases and injuries (Annan et al. 2015). In small and medium-sized enterprises, specifically the construction industry, challenges with OHS implementation are affected by insufficient skilled human resources, poor governmental support for regulatory institutions and inefficient and ineffective organisational frameworks responsible for health and safety standards (Kheni, Dainty & Gibb 2008).

Specific to noise exposure, in Ghana's commercial and progressive economy, NIHL is one of the key factors contributing to OHS risks in construction industries (Puplampu 2012), quarries (Gyamfi et al. 2016), market workforce (Kitcher et al. 2014) and mining (Musiba 2015). Regarding HCPs, Amedofu (2007) conducted a study on the effectiveness of an HCP implemented at a mine in Ghana and the findings revealed that the HCP was indeed effective. However, it should be noted that this study was (1) conducted in one mine only, which was also a surface mine, (2) data were collected retrospectively, using audiometric data and (3) data were collected from only 200 participants. Therefore, this limited evidence from Ghana could explain the high prevalence of ONIHL in this country. Furthermore, this information seems to confirm the fragmented and poorly implemented OHS regulations in this country.

In East Africa, evidence from Tanzania's OHS practices indicates similar findings as in other LMICs. Tanzania has a high rate of injuries, and the small-scale mining sector is largely unregulated (Mrema et al. 2015). In this country, there are several laws and regulations governing OHS practices. These include the Factories Ordinance Cap; Factories (Building Operations and Works of Engineering Construction) Rules of 1985, the Woodworking Machinery Rules of 1955, the Factories (Electricity) Amendment rules of 1985, the Factories (Occupational Health Care Services) Rules of 1985, the Factories (Electricity) Amendment rules of 1985, the Notification of Accidents and Occupational Diseases Ordinance of 1953, Cap 330, Workmen's Compensation Ordinance of 1949 and the Factories (Occupational Health and Safety Services Fees) rules, 2001 (Mrema et al. 2015, p. 541). OSHA administers all these statutes under the Ministry of Labour, Youth Development and Employment. Largely, the Factories Ordinance Cap was limited in scope as it mainly focused on the protection of factory workers' health. Subsequently, the OHSA was enacted and has now become the main legislation governing OHS practices in Tanzania (Mrema et al. 2015). Like in Ghana, this legislation does not cover the self-employed and informal sectors, and over 80% of the workers are not insured by the OSH law, without access to occupational health care services. Additionally, there is a scarcity of occupational health care professionals, specifically occupational medicine practitioners. The available health care workers reportedly lack knowledge and skills in treatment of occupational diseases. Furthermore, the country is reported to lack coordinated OHS research strategy (Mrema et al. 2015). Furthermore, Mrema et al. (2015) enumerates some of the reasons why OHS are not effective in Tanzania and these include:

- globalisation and rapidly growing economy and technological development
- ineffective organisational framework to promote OHS in formal and informal sectors
- limited OHS skills among occupational health care service providers

- limited human technical and financial resources to implement OHS
- poor awareness of OHS regulations among the general public, employees and employers
- poor compliance with OHS regulations and guidelines
- unsafe working conditions in the informal sector
- insufficient OHS training and upskilling
- lack of financial buy-in and commitment by government and key stakeholders to promote OHS activities
- lack of government officials fully committed or motivated to promote OHS laws and regulations
- corruption
- poor interest from employers in providing safe working conditions and environments
- insufficient information on OHS
- limited projects aimed at responding to cross-cutting and sectoral issues related to gender, HIV and AIDS, migrant workers, disabled people and people living in abject poverty.

Within the Southern African context, the death toll in the informal and formal sectors is reportedly very high in South Africa, as approximately 2.3 million deaths occur annually, with 650,000 of them attributed to hazardous substances in the workplace (Tshoose 2014). The *South African Constitution* states that all individuals have a right to an environment that is safe and risk-free. This right is documented in Section 8 of the OHSA (Tshoose 2014). This regulation mandates every employer to provide and maintain a working environment that is not harmful to the health of the employees (Basson, Le Roux & Strydom 2009). Additionally, the COIDA is concerned with compensation for occupational injury or disease sustained by an individual while on duty (Tshoose 2014). Moreover, there are the OHSA and the MHSA is the primary law policing occupational health practice in the mining industry (Guild et al. 2001). The MHSA was established on 15 January 1997, through a tripartite consultation process involving representatives of the state, employers and labour, updating the *Minerals Act 50 of 1991* as the legal framework for regulating OHS in South African mines (Guild et al. 2001).

The MHSA was implemented after a comprehensive policy review conducted by the Leon Commission of enquiry into health and safety in South African mines. The findings of the Leon Commission revealed that the measures taken by the mining sector to protect the workforce from work-related health conditions were not adequate, as there was no decrease in the incidence or the intensity of leading occupational diseases in the mining industry since before 1994 (Guild et al. 2001; Stanton 2003). Subsequently, the Commission recommended a major legislative restructuring, particularly enforcing the health and safety standards (Stanton 2003). Despite all these regulations, the number of fatalities remains high in the South African mining industry, and the mining sector in particular ranks poorly to manufacturing, construction and rail sectors, rendering it an unsafe industry (Teke 2017). Moreover, the OHS regulations do not consider the needs of female workers, with evidence showing that females have unique OHS needs as a result of their anatomy and physiological makeup, and the mining sector lacks the necessary skills to accommodate them. Evidence indicates that inappropriate style and type of PPE is provided by the sector, and that approximately 99% of females are subjected to unhygienic working conditions and do not have access to proper sanitary facilities underground (Tshoose 2014; Zungu 2012). Chapter 2 expands on this and other realities that have an influence on OHS in South African mines.

Furthermore, the OHS regulations in South Africa are not adequately enforced as the penalties for breach of OHS laws are very low, with no criminal sanctions for breaching these regulations. Lastly, issues such as job insecurities, contingent work arrangements, barring of migrant employees from the ambit of social security protection in South Africa and subjection of migrant workers to working conditions that are dirty, dangerous and demeaning are reported within this sector (Manning & Pillay 2020; Posel, Fairburn & Lund 2006; Schenker 2010).

8.2.1. Hearing conservation programmes and occupational health and safety in sub-Saharan Africa

As stated earlier, ONIHL is prevalent in LMICs. Chadambuka et al. (2013) argue that 80% of the burden associated with occupational noise is in LMICs. Although ONIHL is not life-threatening, its impact in LMICs is significant, with HCPs, which are measures aimed at mitigating the impact of ONIHL in industries, not being readily implemented.

The success of HCPs is heavily influenced by the involvement of all stakeholders and the context in which HCPs are implemented (Moroe 2020). This is where all the pillars of the HCPs are implemented (Amedofu & Fuente 2008), in adherence to the hierarchy of control (NIOSH 2016). In relation to the management of ONIHL in the mining sector in sub-Saharan Africa, Moroe et al. (2018) conducted a systematic review to describe the HCPs implemented at various mines. The study included nine studies, of which seven were from South Africa and the remaining two were from Ghana and Zimbabwe. This limited published evidence from this region is problematic. If the burden of ONIHL is heavy in sub-Saharan Africa, this high prevalence should be reflected in the industries' response to this hazard in the workplace. Additionally, considering that industries such as mining, construction, manufacturing and transportation are the economic backbone in Africa and employ most of the working class, there should be more concerted efforts to protecting the workforce involved in these industries. These findings of paucity of contextually relevant evidence echo the sentiments by Mrema et al. (2015) who noted the dearth of comprehensive and well-coordinated OHS research strategy in LMICs. Similarly, in this systematic review, Moroe et al. (2018) noted the dearth of research on HCPs in Africa. This limits the collation of context-specific and responsive evidence that can positively contribute to the effective implementation of HCPs in the local context. Furthermore, the findings revealed that, in cases where HCPs were implemented, they were conducted in a fragmented manner where pillars were not implemented in their entirety, as there was preference for certain pillars over others. In this review, it was noted that that there was a heavy preference for the adoption of use of HPDs. According to the hierarchy of noise control, HPDs are the last defence strategy in the prevention of ONIHL (NIOSH 2016).

The hierarchy of control of HCPs mandates that engineering controls should be the first line of defence (NIOSH 2016). Several authors have postulated that this practice is driven by the fact that implementing engineering controls, particularly *buying quiet*, is costly (Bruce 2007; Khoza-Shangase et al. 2020; Rupprecht 2017; Suter 2012). One of the reasons cited for poorly implemented OHS regulations is lack of resources and infrastructure required for facilitation of implementation (Kheni et al. 2008). A similar case can be made with HCPs, where implementing engineering controls may be costly for LMIC industries, and ONIHL may be competing for budget and prioritisation with other health conditions such as HIV, AIDS and tuberculosis (Khoza-Shangase 2020a).

As far as the pillars of HCPs are concerned, of all the seven pillars, only four pillars (engineering controls, administrative controls, HPDs and education and training) were implemented, to the exclusion of periodic noise exposure, audiometric evaluations and record-keeping. Hearing conservation programmes are evidence-based strategies, and there is rationale for including all the pillars when implementing them. Although the pillars are independent, they are also interdependent; therefore, they should not be implemented in isolation. For example, in implementing the use of HPDs (single pillar), provision of HPDs should be informed by the periodic noise exposure pillar and engineering control pillar to ensure that equipment is emitting noise within the regulated noise levels. Furthermore, the success of this initiative will depend on having a solid education and awareness pillar, which is supported by early screening through the routine audiometry surveillance pillar and administrative controls. Furthermore, there must be measures in place to monitor the programme, driven by the record-keeping pillar. Based on this example, each and every pillar is dependent on other pillars to succeed; hence, HCP pillars are independent and interdependent of each other (Moroe 2020). Therefore, overlooking some pillars potentially undermines the integrity of and the evidence base behind the efficacy of HCPs. When linking HCPs to OHS regulations, in cases where OHS initiatives are implemented, one must acknowledge that they are not holistically inclusive. For instance, workers in informal sectors do not readily have access to OHS services, and migrant workers and females are also excluded, or their needs not fully addressed (Mrema et al. 2015; Tshoose 2014; Zungu 2012). Excluding certain pillars (HCPs) and certain workers (OHS) results in fragmented and poorly implemented regulations (Moyo et al. 2015).

Lastly, most of the studies in the Moroe et al.'s (2018) review had small sample sizes, as such the findings and solutions from these studies could not be automatically and easily generalised to other contexts within the industry in this region. This presents a challenge, as it means industries cannot learn from each other. According to Stewart and Malatji (2018), in OHS, leading practice is concerned with identifying, implementing and disseminating best innovations through encouraging industries to learn from the pockets of excellence existing in the mining industry. This can be achieved when industries conduct studies or implement innovative ideas on a large scale to ensure generalisability and sharing of evidence-based solutions for OHS and HCPs. Furthermore, having larger sample size studies promotes cross-pollination of ideas and knowledge which influences communal learning and sharing of ideas about best practice (Gunasekaran et al. 2017).

■ 8.3. Conclusion

Occupational health and safety is a human rights issue, and the right to a healthy and risk-free working environment is gaining much-deserved attention at the local, regional and international levels. Current evidence suggests that LMICs, particularly the African continent, lack appropriate OHS regulations and control measures. Therefore, there should be a deliberate move towards prioritising OHS regulations because of the reality that neglecting these regulations has catastrophic consequences for Africa. In developing and or implementing these regulations, there should be a clear assessment of the needs of the industry in each country, considering the needs of the intended end-users, with all stakeholders considered. The regulations should be comprehensive and consider the potential burden of diseases and injuries that may be prevalent in the industry, as in South Africa's quadruple burden of disease. Local industries can learn from HICs; however, lessons learned from these countries should always consider contextual relevance and responsiveness (Khoza-Shangase 2022).

Chapter 9

Hearing conservation programmes in the context of burden of disease in South African mines

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9.1. Introduction

Global and emerging local evidence exists to indicate that ONIHL is influenced by numerous factors (Amiri et al. 2015; Amjad-Sardrudi et al. 2012; Bowens 2018a, 2018b; Brits et al. 2012; Chen, Su & Chen 2020; Concha-Barrientos, Campbell-Lendrum & Steenland 2004; Khoza-Shangase 2020a). This evidence shows that their combined effect with noise exposure may have synergistic, additive, potentiating or antagonistic effects for the individual exposed. Chapter 3 is devoted to these factors and their effects on NIHL. The factors in Chapter 3 have been divided into four groups of factors: (1) personal factors (e.g. genetic background, gender, age, smoking,

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contextual diseases), (2) physical factors (e.g. heat and vibration), (3) occupational factors (e.g. excessive noise exposure, workload and not using PPE) and (4) chemical agents (e.g. solvents and heavy metal) (Golmohammadi & Darvishi 2019). Some of these factors fall under the burden of disease umbrella, which is the quadruple burden of disease (QBoD) in the South African context (Khoza-Shangase 2020a; WHO 2018b).

This chapter interrogates HCPs in the context of the burden of disease in South African mines. The chapter commences by presenting background to HCPs within the South African context with an overview of the QBoD that the country is grappling with. The chapter then delves into more detail about the impact of this QBoD, excluding maternal and child mortality, on ONIHL and HCPs within the South African mining industry. Specifically, relationships between communicable diseases (HIV, AIDS and tuberculosis [TB]), noncommunicable diseases (NCDs) (e.g. chronic lung diseases, cancer and diabetes) and injury and trauma to ONIHL are explored. The author then concludes the chapter by highlighting the value of the inclusion of the burden of disease in benefit and risk evaluations of HCPs, with a recommendation for comprehensive and effective PDMS in South African mines as a goal to achieve positive preventive outcomes in this sector.

The WHO (2018) stated that South Africa faces a QBoD resulting from (1) trauma and injury, (2) child and maternal mortality, (3) NCDs such as diabetes, cancer, mental illness, chronic lung diseases, cardiovascular diseases and hypertension and (4) communicable diseases such as TB, HIV and AIDS. Hessel (2008) described the term burden of disease as:

> [*T*]he total, cumulative consequences of a defined disease or a range of harmful diseases with respect to disabilities in a community. These consequences include health, social aspects and costs to society. The gap between an ideal situation, where everyone lives free of disease and disability, and the cumulated current health status, is defined as the burden of disease. (p. 94)

Hessel (2008) further narrated how the methodological concept to calculate the global burden of disease was established through a collaborative effort between the WHO, World Bank and Harvard University in the 1990s. This concept was grounded significantly on the statistical measurement of the disability- adjusted life years (DALY), which basically provides a summation of the time lost because of early mortality as well as the time expended in a constrained health state. Specifically, WHO (2019) stated that the burden of a particular disease or condition is projected by summing up two factors: (1) the total number of years of life an individual lives with disability because of the disease (called years of life lived with disability [YLD]) and (2) the number of years of life an individual loses because of premature death because of the disease (called years of life lost [YLL]). Adding together the YLL and YLD provides one number that estimates disease burden, termed DALY. One DALY is reported to symbolise the shortfall of one year of life lived in full health.

Within the South African context, the QBoD presented is what has been documented to lead to premature mortality and loss of health because of diseases, injuries and risk factors (WHO 2018b).

Estimating the burden of disease is argued to be important for any country and or region in the world for reasons over and above enhancing global public health care. This is because both international and local health policies and priorities would be founded on precise and consequential health evidence (WHO 2019). The WHO (2019) asserted that if the burden of disease, globally and or nationally, is not calculated or accurately measured, policymaking will be poorly informed. This would then lead to poor or failing public health care, which then serves as a barrier to the achievement of the health-related UN Millennium Development Goals of 2000 (MDGs). The Millennium Development Goals of 2015 are the eight international development goals that were agreed upon by the United Nations' Millennium Summit in 2000, to which South Africa is a signatory (World Health Statistics 2015). The WHO (2019) stated that estimating the burden of disease aids countries, regions and the globe in confronting the difficulty of directly translating health data into policy. This data translation challenge is reported to be caused by the following: (1) health information from regular statistics or epidemiological studies being disintegrated, where the focus can be placed on fatal health results or where data are only partially available, (2) overestimation of mortality by studies that investigate particular conditions, mainly because numerous co-occurring conditions may add to and contest for the cause of death and (3) exact comparative appraisals of the cost-effectiveness of diverse health interventions impossible to compute through traditional statistics (WHO 2019).

Burden of disease has a significant influence on hearing function across the lifespan and in various sectors in South Africa (Fagan & Jacobs 2009; Kanji & Khoza-Shangase 2019; Khoza-Shangase 2020a, 2021a, 2021b; Mulwafu et al. 2017; Pillay et al. 2020; Swanepoel 2006). In ONIHL, this influence can be where the disease is a direct cause of hearing impairment (primary cause), where the disease leads to opportunistic conditions that lead to hearing impairment (secondary cause) or where treatments used to treat the disease cause hearing impairment (iatrogenic cause) (Khoza-Shangase 2020b).

Recently, the burden of disease has been globally impacted by the novel coronavirus disease 2019 (COVID-19), which is the current major public health care burden in the world (Gebru et al. 2021). Hofman and Madhi (2020) described the unanticipated costs of COVID-19 to South Africa's QBoD. Over and above the negative impact that COVID-19 has had on the country's economy, a significant impact has been observed and experienced by the health care system that has been disrupted and placed under severe strain. The urgency of the need to contain and manage the pandemic has reordered priorities for health, with COVID-19 taking significant focus. Strategies to contain and mitigate the impact of COVID-19 have included limiting the spread of the infection through social behavioural measures such as sanitising and hand-washing, physical distancing and wearing of face coverings in public, with the lockdown of the country being a more drastic infection containment strategy. Despite these measures, the number of infections still rose with increased numbers of hospital admissions and deaths (Roberton et al. 2020; Steyn 2020), with new variants being constantly discovered. Steyn (2020) claimed that hospitals have also reprogrammed treatment units to accommodate COVID-19 patients, while other hospitals have provisionally closed their doors, with all these changes directly impacting the burden of disease management (Jewell et al. 2020; Shange 2020; Steyn 2020).

Hofman and Madhi (2020) highlighted that it is important that South Africa carefully balances COVID-19 management with that of QBoD and remains cognisant of the opportunity costs associated with shifting priorities. These authors advance the following recommendations to facilitate this careful balancing:

- Health care services must ensure that both demand-side and supply-side needs and challenges are addressed in inventive ways to allow for access by most of the South African population.
- South Africa must utilise priority-setting approaches that allow it to ensure that the number of lives lost to or saved from COVID-19 is considered and not only lives that could be lost by interruption of the provision of essential services.
- South Africa must recognise both the direct and indirect impacts of the COVID-19 pandemic on comorbidities.
- South Africa must recognise the psychosocial effects of the pandemic, as well as all efforts towards containing its spread and negative outcomes.
- The country must see this COVID-19 pandemic as an opportunity to transform its health care system and services through collaborating with experts who can think about innovative transformative ways that can be implemented to renovate and innovate health care services.

Under non-COVID-19 conditions, South Africa has experienced challenges in addressing the country's QBoD (Bradshaw et al. 2019; Hofman & Madhi 2020). Inequalities and social factors have continued to play an inescapably prevalent role in the patterns of disease the South African population suffered. Coovadia et al. (2009) described how massive income disparities, high levels of extreme violence, the migrant labour system and its consequent destruction of family units, as well as discrimination along gender and racial lines have impacted health and health care delivery in the country. Furthermore, social determinants of health have been highlighted, especially relating to the HIV, AIDS and TB epidemics and injuries, as well as the health challenges linked with poverty. Hofman and Madhi (2020) asserted that this challenge with addressing the burden of disease is created by the co-occurrence of TB and HIV with NCDs and obesity, persistently poor child and maternal mortality outcomes and violence and injury, all in the context of the inequities caused by the country's poor social determinants of health. Bradshaw et al. (2019) maintained that based on mortality data analysis in South Africa over the past 50 years, significant understandings into population health have foregrounded the necessity for health promotion, primary health care and intersectoral initiatives to enhance health and lessen the existing inequalities, while improving the social determinants of health.

COVID-19 and its allied loss of income because of the lockdown have negatively influenced social determinants of health. Hofman and Madhi (2020) reported that the nationwide COVID-19 lockdown has created shifts on both the supply and demand sides of health care. These authors reported on the supply side seeing shifts in human resources to manage the pandemic, causing inadequate services for diagnosis, treatment and prevention of other health care challenges and needs. This is while the demand side is recording the population's avoidance of health care facilities because of various reasons. All these had a negative impact on the management of QBoD, resulting in poorer health outcomes (Hofman & Madhi 2020). The pressure of COVID-19 on the health care system directly, with this aggravation of the multiple disease burden, places additional pressure on the national health care system. This added that strain carries cost and human resources implications for the country to deliver standard care during a pandemic (Shange 2020; Steyn 2020).

Hofman and Madhi (2020) cautioned that, until a cure or a vaccine for COVID-19 is available and accessible, it is imperative that the country desists from diverting finite resources exclusively to the pandemic. They recommended cautious planning around priorities, taking careful cognisance of costs and benefits of standard health care interventions and services. The author of this chapter believes that even with the now available vaccines, the same argument holds, particularly with the continuous discovery of the number of COVID-19 variants. This, these authors maintain, is vital to the success and sustainability of gains made in public health care in the past decades, while concurrently managing the COVID-19 pandemic. A strategic management of the QBoD, with or without COVID-19, is also important because of the impact that these have on other health care conditions and disabilities, such as ONIHL.

As part of an exploration of realities confronting South African mining HCPs, Chapter 2 provides an overview of the burden of disease as one of these realities. The author of this chapter laments how pre-COVID-19 health care resources and budgets were directed towards curbing mortality. For example, HIV and AIDS, as part of the QBoD conditions, took a lion's share of the health budget, contributing substantially to the disease burden. The rest of the conditions, namely TB; NCDs; maternal, newborn and child health; and injury and violence are recognised to be associated with hearing loss and have specifically been found to worsen ONIHL. Chapter 3 presents these as part of the contextualised risk factors for ONIHL within the African mining industry.

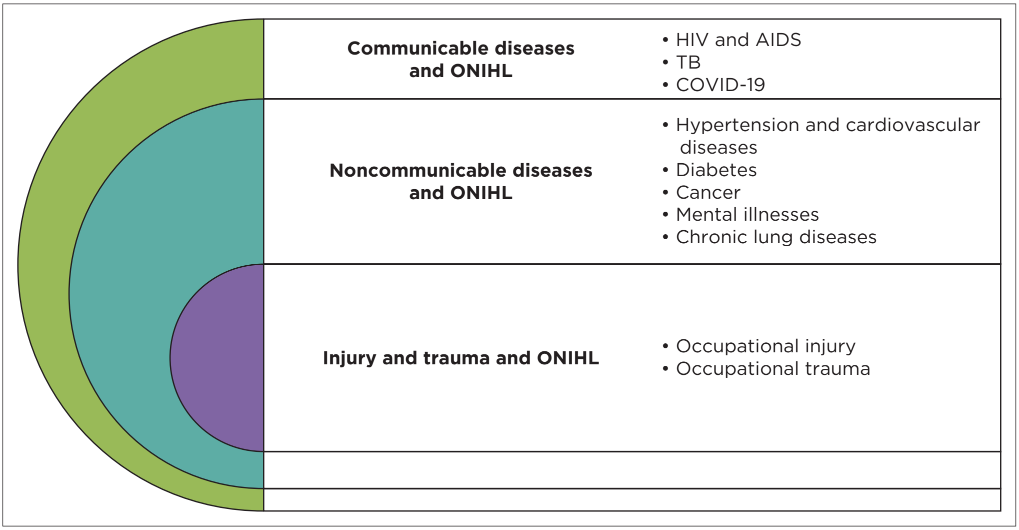
In a scoping review of HIV, AIDS and TB as burdens of disease in ONIHL in South Africa, Khoza-Shangase (2020a) motivated careful cognisance of these conditions in South African HCPs. This is because sufficient evidence has affirmed that ONIHL is a complex condition with multiple influencing factors and does not occur in isolation from these risk factors. This author further asserted that the consequences of the burden of disease in audiology and otology, such as in ONIHL, are pivotal because some diseases cause hearing loss in multiple ways. For example, disease directly causing hearing loss is a primary effect; disease leading to a secondary or opportunistic condition that causes hearing loss is a secondary effect; hearing loss as a side effect of treatment options for those diseases is an iatrogenic effect. A worker with concomitant exposure to such diseases and excessive noise levels can create an even bigger challenge to efficacious HCPs if these interaction dynamics are not considered in the planning, application and ongoing reviewing of HCPs (Khoza-Shangase 2020a).

For the year ending 2019, UNAIDS reported that among the LMICs, South Africa has among the uppermost HIV and AIDS prevalence rates globally, with a documented 7.7 million individuals living with HIV – at a rate of 20.4% in adults (UNAIDS 2020). As far as the 90:90:90 targets are concerned, in the same period, estimates for South Africa reflected that 92% of South African adults with HIV knew their status, with 70% of adults on antiretroviral treatment (ART) and 64% virally suppressed (UNAIDS 2020). As far as TB is concerned, a 20% increase in the number of TB infections, when compared to 2018 numbers, has recently been reported by WHO (2020). During the year ending 2019, around 360,000 people were reported to have fallen ill with TB in South Africa. Positive reports were, however, documented about the treatment success rate for drug-resistant TB, which was seen to have improved in the same period with the rollout of the less ototoxic treatment, bedaquiline, being documented (Khoza-Shangase & Prodromos 2021).

Statistics for the country on HIV, AIDS and TB are mirrored in the South African mining industry as reported by Stuckler and colleagues (2011, 2013), with the mining industry reported to have the highest prevalence of these diseases. The increased prevalence of HIV in South Africa has been closely linked to dramatic increases in TB (Chaisson & Martinson 2008). In 2006, Reddy and Swanepoel (2006) reported that approximately 30% of South African mineworkers acquire HIV in the first 18 months of employment at the mines, with this number significantly higher in 2012 in one of the South African mines, where it was documented that approximately 85% of their employees were diagnosed with TB and HIV (AngloGold Ashanti 2012).

The success of the ART plan implemented by the South African mines in 2002 has reportedly led to a decrease in the TB rates, which became noticeable in 2008, with the current incidence of TB in Minerals Council (previously Chamber of Mines) members being fewer than the estimated incidence (MCSA 2020). Chapter 2 argues that because of the well-documented synergistic effects of ototoxicity and excessive noise exposure (Khoza-Shangase 2019, 2020a; Valente, Hosford-Dunn & Roeser 2008), it is important for the South African mining industry and the audiology community to take cognisance of the burden of these diseases and their influence in South African HCPs. Of the South African QBoD, with the exclusion of maternal and child mortality, three will be reviewed in this chapter, with a focus on their impact and/or relationship with ONIHL.

As evidence suggests that South Africa remains one of the LMICs with inadequate health outcomes as well as elevated mortality rates associated with the country's unique QBoD (Institute for Health Metrics and Evaluation [IHME] 2018; Pillay-van Wyk et al. 2016; Rohde et al. 2008), the author of this chapter argues that it is prudent that reviews of these diseases as occupational health conditions in the South African mining context occur against the backdrop of this unique QBoD. Management of occupational health conditions cannot occur in a manner that is detached from this disease burden (Khoza-Shangase 2020a), as depicted in Figure 9.1. Such consideration is particularly true in ONIHL, which is recognised to have multiple influences associated with QBoD.



Key: AIDS, acquired immunodeficiency syndrome; COVID-19, coronavirus disease 2019; HIV, human immunodeficiency virus; ONIHL, occupational noise-induced hearing loss; TB, tuberculosis.
Source: Author's own work.

FIGURE 9.1: Burden of diseases influencing ONIHL in South Africa.

9.1.1. Relationship between communicable diseases (HIV, AIDS and TB) and ONIHL

A recent scoping review (Khoza-Shangase 2020a) found significantly limited published evidence on the burden of HIV and AIDS and TB and its relation to ONIHL in South Africa, with only two publications particularly relevant to ONIHL within the South African context. Besides these two mentioned publications, the rest of the findings highlighted a considerable African and international lacuna in the evidence around the scoping review question. The review question was: 'Does ONIHL research consider the burden of disease from HIV and AIDS and TB as a potential influence in HCPs and what has been documented in the literature on this?' This review concluded that this apparent dearth of studies into the impact of TB and HIV and AIDS on ONIHL in the mining context raises crucial inferences regarding the responsiveness, preparedness and therefore proactive nature of HCPs within the mining industry. The two publications on TB and ONIHL (Brits et al. 2012; Khoza-Shangase 2020a) revealed a significant influence of the TB treatments on the nature, degree and development of ONIHL, which is explained as being because of the synergistic effects of the two factors (ototoxicity and noise exposure) on the ear. The rest of the publications' close analysis exposed that research in occupational health has not recognised ONIHL as a complex condition that does not occur in isolation but in context where numerous risks or influencing factors interact. These other risk or influencing factors include pharmacological treatments that workers are prescribed for conditions such as HIV, AIDS and TB. Khoza-Shangase (2020a) concluded the review by highlighting the value of strategic HCPs, where workers at increased risk because of co-occurring ototoxicity undergo ototoxicity monitoring as part of their HCPs, with explorations around the potential use of otoprotective and chemo-protective agents to prevent worsening ONIHL (Khoza-Shangase 2010a, 2010b, 2011, 2017).

The strategic HCPs within the South African mining population must ensure the inclusion of ototoxicity monitoring and management in HIV, AIDS and TB. The need for auditory evaluations for early detection of hearing threshold changes because of drug therapy that is extensively established is raised in this population, with the management of the concomitant exposure to excessive occupational noise raised. Within HCPs, evidence has indicated that ignorance of ototoxicity monitoring in patients on treatment for TB leads to an inability to manage the employees' hearing outcomes, which have been found to be significantly worse in this population (Brits et al. 2012; Khoza-Shangase 2020b). Careful individualised HCPs that include ototoxicity identification and monitoring would allow these employees to benefit from the various treatment options available in ototoxicity monitoring. These options include prescription of alternative less ototoxic drugs, for example, bedaquiline for MDR-TB (Khoza-Shangase & Prodromos 2021), decreased dosages or modified drug regimens if ototoxicity is identified at the initial stages of treatment (Lonsbury-Martin & Martin 2001). Khoza-Shangase (2020a) also argued that ototoxicity monitoring in this population would facilitate redeployment of the affected worker from noisy workspaces during treatment with ototoxic medication to avert the synergistic effect of ototoxic treatments and noise on the ear, thereby preventing further toxin exposure that increases the risk of ONIHL.

The limited published evidence in this area highlights a significant need for research within the South African context on the highly prevalent burden of disease conditions as they relate to ONIHL and HCPs both within the African context and internationally, a call that is made in Chapter 3. This call is important because reviewed studies showed investigations into health and or diseases in miners that were not establishing associations among these and between them and occupational health prevention initiatives such as HCPs. These investigations focus on the following aspects, which Khoza-Shangase (2020a) argued as having significant implications for the burden of disease influence on HCPs: (1) research into increased efforts towards strategies aimed at dealing with TB and HIV in the mining sector (Barwise et al. 2013; Kistnasamy et al. 2018); (2) reviews on health risks of gold miners (Eisler 2003); (3) studies focusing on occupational health challenges confronting the Department of Health, including protecting current employees against tuberculosis and caring for ex-employees with occupational health disease (Adams et al. 2012); (4) OHS in mining compilation on the state of affairs in 16 mining countries (Elgstrand & Vingård 2013); and (5) research into the 85 dBA regulation point in South African mineworkers (Edwards 2009). All these publications are silent on the impact of the burden of disease on ONIHL or its interaction with ONIHL, although they address the burden of disease directly and or indirectly.

Brits et al. (2012), in their investigation on the hearing profile of South African gold mineworkers with and without TB, found worse hearing function where thresholds were substantially raised in the group with TB when compared with the control group. These authors also found that the progression of hearing loss was significantly worse in the TB group over time, regardless of whether they were on single or multiple treatments. Similar findings were recently reported by Khoza-Shangase (2020a) based on a retrospective data review. In this recent study, age and HIV were included as additional possible influencing factors. Results affirmed that gold mineworkers with a history of TB treatment have worse hearing thresholds in the high frequencies than the group without this history. Additionally, a negative correlation was found between age and HIV and hearing loss in this population. Khoza-Shangase (2020a) submitted results from this investigation as motivation for strategic HCPs.

The current COVID-19 pandemic, as a burden of disease, also presents significant challenges to the South African mining industry. Mbazima (2020) investigated the effect of COVID-19 and its allied lockdowns on mining industries globally and established numerous scenarios through modelling. Limited evidence has been gathered on the influence of this pandemic on hearing function, and consequently ONIHL, except for the obvious challenges it creates for the implementation of HCPs, where the spread of the virus containment measures must be adhered to, thus affecting workers' testing, education, counselling, etc. Mbazima (2020) stated that COVID-19 has led to the mining industry having to acclimatise to novel ways of operating to safeguard the health and safety of employees, and this is applicable to the implementation of HCPs. In a recent special issue collection on the impact of COVID-19 in speech, language and hearing (SLH) professions in LMICs (Khoza-Shangase et al. 2022), findings highlighted a need for more research into the initial reports of sudden unexplained cochleovestibular symptoms (Khoza-Shangase, 2022), as well as changes to the middle ear status – structure, function and pathology during COVID-19 (Sebothoma & Khoza-Shangase, 2022).

9.1.2. Relationship between NCDs and ONIHL

Noncommunicable diseases (NCDs) (e.g. diabetes, cardiovascular diseases and hypertension, cancer and chronic lung diseases such as asthma and mental illnesses) are recognised as the leading causes of mortality and disability globally (WHO 2018a). Ratsela (2018) reported that more than three in five individuals die from NCDs, and NCDs account for more than half of the worldwide burden of disease. The WHO (2018a) projected that approximately 41 million individuals die from NCDs annually, with LMICs being hit the hardest by this mortality rate. The WHO (2018a) calculated that worldwide, 52 million people will perish from NCDs by 2030, if preventive measures are not implemented. Over the past decade, South Africa has recorded increased numbers of individuals with NCDs, an increase to numbers that now surpass that for communicable diseases (WHO 2018a). Results from the first NCD Countdown 2030 Report indicate that, of the 186 countries being monitored, South Africa is one of the countries in danger of not achieving the United Nations' goal to decrease NCDs by 2030. This is a serious concern in the context of this chapter.

Ratsela (2018) made a case that although the NCD Countdown findings are from researchers' forecasts for the upcoming decade, current evidence from former investigations does reveal that South Africa has the topmost rate of obese and overweight individuals in sub-Saharan Africa. Studies have also demonstrated that five out of every 10 South African adults have hypertension. The WHO (2018a) reported that NCDs account for 51.9% of all deaths in South Africa, with the chances of dying from an NCD being significant. The reported proportional mortality of NCDs reflects 19% because of cardiovascular diseases, 10% cancer, 4% chronic respiratory diseases, 7% diabetes, 9% injuries and 11% other NCDs, with 40% communicable, maternal, perinatal and nutritional conditions.

Chapter 3 presents an overview of a relationship between what is termed contextual diseases in the chapter – NCDs according to the QBoD. Contextual diseases such as diabetes, hypertension and cardiovascular diseases, elevated triglycerides and cholesterol have been reported to exacerbate hearing loss, and hearing loss has also been documented to worsen these burdens of diseases (Golmohammadi & Darvishi 2019; Ishii et al. 1992; Lie et al. 2016). These listed conditions have been discovered to be substantially associated with NIHL (Agrawal, Platz & Niparko 2009; Fransen et al. 2008; Fuortes et al. 1995; Ishii et al. 1992; Yoshioka et al. 2010), where they have been found to aggravate NIHL and exacerbate the adverse effects of noise. In a national cross-sectional survey by Agrawal et al. (2009) where the goal was to assess and compare the impact of cardiovascular risk factors and noise exposure on frequency-specific audiometric thresholds among US adults while evaluating synergistic interactions between them, findings revealed that independently, noise exposure was associated with high-frequency hearing loss. However, with cardiovascular risk (because of diabetes and smoking), noise exposure led to hearing loss in both high and low frequencies. These authors posit that this interaction outcome is probably because of cochlear vulnerability caused by microvascular insufficiency. Findings from this study led the authors to conclude that this interaction provides proof of the principle that certain pre-existing medical conditions can potentiate the impact of excessive noise exposure on hearing, thereby exacerbating ONIHL.

Such findings are important for preventive programmes in primary health care initiatives within the mining industry. Ishii et al. (1992) investigated other factors that predispose individuals to NIHL, other than chronic noise exposure. Findings from this study showed that age and diabetes were significant predictors of severe NIHL, with the results proposing that an individual with non–insulin-dependent diabetes mellitus (NIDDM) who is also exposed to excessive noise at work is more likely to develop severe NIHL than an individual without NIDDM. Fuortes et al. (1995) also found that selected cardiovascular risk factors such as cholesterol, smoking and blood pressure were associated with hearing loss.

Yoshioka et al. (2010) investigated the impact of arterial sclerosis on hearing in individuals with and without occupational noise exposure. Findings indicated the limited effect of arterial sclerosis on hearing, but this changed in middle-aged and elderly males. Findings from this study also revealed that arterial sclerosis worsens the adverse effects of noise on hearing. These authors argued that their findings suggest that early detection of arterial sclerosis might be influential to the hearing prognosis after middle age, particularly for noise-exposed males. This evidence is important for hearing conservation in noise-exposed older males, who are also at risk purely because of advancing age. In another study, Fransen et al. (2008) discovered that smoking (as well as high body mass index [BMI]) substantially worsened high-frequency hearing loss, with the effect being dose-dependent. These findings highlight the importance of health awareness programmes around healthy lifestyles to prevent hearing loss that can be exacerbated by excessive long-term occupational noise exposure. The treatments for cancer increase the risk of ototoxicity (Landier 2016), which acts synergistically with exposure to noise to lead to worsened ONIHL (Khoza-Shangase 2019, 2020a). Despite the aforementioned findings, Golmohammadi and Darvishi (2019) suggested that more longitudinal studies be conducted on the combined effects of excessive exposure to noise and NCDs. This recommendation is appropriate for the South African context, where NCDs are part of the QBoD.

9.1.3. Relationship between injury and trauma and ONIHL

The 2015 Global Burden of Disease study documented that 8.5% of global deaths, which averages to approximately 4.7 million people, are because of trauma (Haagsma et al. 2016). Zaidi et al. (2019) contended that sub-Saharan Africa carries an uneven burden of this trauma-related mortality. Records indicate that the significant contributors to the burden of injuries and trauma in South Africa are interpersonal violence and road traffic injuries (Norman et al. 2007; Prinsloo, Kotzenberg & Seedat 2007). Norman et al. (2007) reported that, in South Africa, the rate of deaths because of trauma is six times the global rate, with the rate of road traffic injuries being twice the global average.

Regarding the aetiology of injury and trauma, the Mining Review Africa (2020) reported that, based on the 2019 mining health and safety statistics, the year 2019 recorded the least number of fatalities, with only 51 deaths in South Africa. This record is a 37% improvement in deaths when compared to the previous year, with a 2% decrease in occupational injuries. These numbers are said to be because of the South African mining industry's continued commitment to *Zero Harm*. Roger Baxter, Chief Executive Officer of the MCSA noted that (Mining Review Africa 2020):

> The path to Zero Harm was never going to be an easy or simple one. And we have experienced setbacks. While the industry's safety and health performance during 2019 is a significant progress on what we have been able to achieve in the past, we recognise that our journey is far from over. (n.p.)

The Mining Review Africa (2020) highlighted that the MCSA has noted that the reduction in the number of injuries must be a key focus area for all industry stakeholders.

The author of this chapter argues that HCPs can significantly contribute towards this goal of reducing injuries and trauma in the South African mining industry. Published evidence suggests an association between excessive noise exposure, ONIHL and injuries. For example, Girard et al. (2015) investigated a relationship between occupational injuries that led to hospital admission and ONIHL in a group of male employees who were exposed to noise at levels ≥ 80 dBA. An association was established where with each dB of hearing loss, a statistically significant risk increase was found. Another association was observed between the risk of injury and working in a workplace where the ambient noise was ≥ 100 dBA. These authors concluded that careful monitoring of noise and ONIHL is important from a safety perspective, particularly where ambient noise levels are intense. Yoon et al. (2015) found that work contexts where there is excessive noise exposure are significantly linked with high incidents when compared to those with excessive dust exposure. The clearly established relationship between noise exposure and elevated risk of occupational injury was found to be a dose-response relationship, which implies that approaches adopted to minimise noise also decrease the risk of occupational injury. This dose-response relationship highlights the indirect benefit of HCPs on occupational injuries, which should be used as motivation for increased efforts towards efficient HCPs as these have an effect of preserving not only hearing but also life. More studies are required in this area.

Cantley et al. (2015) examined the relationship between acute workplace injury risk, ambient noise exposure and hearing acuity. Findings from this study affirmed other findings indicating that excessive noise exposure (> 82 dBA) is linked to increased risk of occupational injury in a monotonic and statistically significant dose-response pattern for all injuries, with severe injuries linked to intense noise. Hearing loss, in this study, was also associated with an increased risk for all injuries. This is where workers with normal hearing presented with less increased risk (6%) to all injuries than those with a mild hearing loss who presented with a 21% increased risk to all injuries. These findings can also be used to argue for the importance of HCPs within South African mines.

■ 9.2. Conclusion

The QBoD and its influence on ONIHL in South Africa requires focus, as this is one of the biggest health challenges that South Africa grapples with. Internationally, significant progress has been made in terms of establishing this evidence; however, substantial room still exists for additional investigations, particularly in LMICs such as South Africa. Opportunities exist for the burden of disease prevention strategies in the mining industry, with a heightened focus on occupational health risk reduction. Occupational noise-induced hearing loss risk reduction as well as management requires the existence of prudently formulated, proficiently executed and reviewed HCPs that consider the burden of disease and its influence. These HCPs need to be context-sensitive, context responsive and contextually relevant. Such comprehensiveness in the inclusion of risk factors and burden of disease in HCPs will not only facilitate the efficacy of HCPs but will improve the quality of life of employees, including saving employees from injuries and death.

In a viewpoint publication, Khoza-Shangase and Moroe (2020) highlighted critical variables and strategic indicators that are important to reflect on for planning of more efficacious HCPs in South African mining, while underlining the core role that audiologists play in this context. The current practice in the South African mining industry where audiologists' involvement in occupational audiology vigilance through HCPs is very limited, needs to change. Currently, where occupational audiology is in place, it is performed by paraprofessionals (audiometrists), and it does not appear to be strategy-driven, systematic or comprehensive in nature. The current chapter and Chapter 3 have also illustrated how restricted these South African HCPs are in terms of comprehensively addressing the impact of risk factors and burden of disease in ONIHL. This failure is deepened by the current uncertainty around which regulatory body should enforce employer accountability as far as occupational health matters are concerned in the mines, as both the mining industry regulating body and the HPCSA seem to be silent and/or peripherally regulating. This regulatory authority uncertainty is a serious indictment and could be because currently, the Department of Labour regulates its occupational health matters, which arguably should be under the direct control of the Department of Health. The limited involvement of audiologists in the crafting of health and safety regulations and policies, as well as their exclusion in risk–benefit assessments of HCPs' conceptualisation and reviewing processes, worsen this South African mining industry reality.

Because of their training, hence ONIHL and HCPs falling under their scope of practice, audiologists' knowledge and understanding of the burden of disease and its impact on hearing function places them in good stead to conduct risk–benefit evaluations for this industry. Khoza-Shangase and Moroe (2020) recommended increased attention to these risk–benefit evaluations by the occupational health community as part of OHS vigilance approaches, particularly because of the consistent high prevalence of ONIHL in the mining industry globally. With the high prevalence of the QBoD in South Africa, and in South African mines, well-defined roles for the audiologists within the risk–benefit evaluation team are vital, with them becoming more central and leading in these processes. Furthermore, in this process of clarifying roles, the

MCSA should become more visible and central within the multistakeholder and multidisciplinary OHS team in safeguarding compliance with regulations. Khoza-Shangase and Moroe (2020) recommended that the MCSA and South African audiologists thoroughly scope the context (in this case, including scoping the prevalence of burden of disease and its interaction with excessive noise) and perform risk–benefit evaluations including options analysis for the South African mining context – as part of the comprehensive planning of efficacious HCPs.

For appropriate risk–benefit evaluation, the scoping of the context referred to requires that large sets of data be collected, captured and appropriately analysed. This process requires utilising appropriate data record-keeping systems that are of value not only for efficient HCPs but also for research purposes, whose evidence allows for evidence-based best practice within South African mines. Ntlhakana, Khoza-Shangase and Nelson (2020) critiqued the current PDMS used in South African mines and concluded that significant gaps exist in the mine's PDMS for it to be of significant value to HCPs. These authors argued that an inclusive integrative data management programme is required. The author of this chapter recommends that this data management programme includes the QBoD and all risk factors presented in Chapter 3, as these are important indicators for efficacious HCP implementation in South Africa.

Chapter 10

Hearing conservation programmes in the context of tele-audiology in African mines[1]

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■ 10.1. Introduction

As the use of telepractice steadily expands, with coronavirus disease 2019 (COVID-19) having accelerated this model of health care service delivery recently, the African mining industry and audiologists have a unique opportunity to apply this model to increase access to occupational audiology, where it is currently limited (Moroe et al. 2018). Audiology Australia (2020)

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[1] Sections of this chapter represent a more than 50% reworking of the following publication: Khoza-Shangase and Moroe (2020:670).

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argued that the COVID-19 pandemic has led to a sudden and rapid expansion of tele-audiology services, which has the potential to transform audiology in the longer term beyond COVID-19. While acknowledging that tele-audiology and its possibilities have been in existence for a while globally, the advent of COVID-19 has done the following (Aggarwal, Patel & Ravi 2020; Claridge & Kroll 2021; Fong, Tsai & Yiu 2021; Khoza-Shangase, Moroe & Neille 2021; Khoza-Shangase 2022; Lam, Lee & Tong 2021; Mansuri et al. 2021; McGill & Dennard 2021; Sebothoma et al. 2021):

1. The health care delivery conditions imposed by the health and safety regulations around virus containment have hastened and widened the scale of use, with support from regulators as well as medical aid funders.
2. The COVID-19 conditions have created an important precedent for the ability of audiologists to provide clinically appropriate services remotely via video or phone without compromising clinical outcomes, including raising important implications around patient-site facilitators.
3. COVID-19 has opportunistically allowed patients an opportunity to experience telehealth, patients who may, under normal circumstances, have never opted for this method of accessing health care.
4. COVID-19 has forced audiologists who would, under normal circumstances, have never utilised tele-audiology either solely or in tandem with face-to-face (hybrid) clinical care, to become flexible and innovative in their ear-and-hearing health care provision.

Telepractice in the form of tele-audiology allows for the development and provision of ear-and-hearing health care services to individuals who may otherwise have limited and or no access to these services. By innovative initiatives, such as the use of mobile apps, mobile clinics, teleconferencing and more (Wolfgang 2019), audiologists can be at the forefront of e-health as the world adapts towards non-traditional, alternative and complementary approaches of health care provision. Audiologists can access this exciting opportunity to implement tele-audiology in most existing practices with minimal additional training and equipment purchases.

The American Speech-Language-Hearing Association (n.d.) and Audiology Australia (2020) identified tele-audiology as an appropriate alternative model of service delivery for ear-and-hearing health care that encompasses both diagnostic and intervention services. Intervention services can include counselling and education for clients and their family or carers (Maluleke & Khoza-Shangase, submitted). Wade, Eliott and Hiller (2012, 2014) also argued that over and above offering an improved patient choice of service delivery and increasing access to services in remotely located areas and home-based intervention, tele-audiology is valuable in lessening adverse events and improving health outcomes. This chapter, following from Chapter 2 on realities confronting HCPs in South African mines, explores this alternative method of audiology care delivery, with the goal of universal ear-and-hearing health care delivery in all mines. The chapter begins by describing tele-audiology and its potential in LMICs, with a particular focus on the African continent, and a discussion of the various types of tele-audiology than can be used either singly or in combination. The authors then justified why the use of tele-audiology should be more carefully considered in ONIHL and HCPs within the African context. A telehearing conservation programme (tele-HCP) model is then recommended for audiologists working in occupational health, with considerations that need to be kept in mind during the application of tele-audiology within the African mining industry presented. The chapter ends with the authors calling for thoughtful consideration of this model of service delivery within HCPs in the African context. Although the chapter tends to use more examples from the South African context, where most available evidence comes from, recommendations made are generalisable to the rest of the continent where contextual realities are very much similar to, or worse than, the South African context.

Khoza-Shangase and Moroe (2020) stated that regardless of tele-audiology being a relatively new service delivery model, careful consideration of its use as a service delivery platform is required in the African context. The fact that tele-audiology is chiefly useful in resource-constrained settings, the reality of demand far superseding capacity in Africa and the prevailing need for scaling up audiology professionals' implementation and management of HCPs as areas that fall under the audiologists' scope of practice all provide a strong rationale for this consideration. Because of the documented inability of the African mining industry to eliminate ONIHL, as detailed in Chapter 4, alternative strategies to implement and monitor HCPs, such as the use of tele-audiology, are critical.

Tele-audiology, a service delivery approach to provide ear-and-hearing health care services to under-served populations utilising information and communications technology (ICT), is a growing response and solution to the intensifying need for audiologic services that is significant across the world (Khoza-Shangase & Sebothoma 2022; Ravi et al. 2018; WHO 2018a). Barriers to accessing health and health-related services in LMICs result in a greater need for these services (Khoza-Shangase 2021; Ramkumar 2020; Sebothoma et al. 2021). Saunders (2019) highlighted that even in HICs, tele-audiology can potentially support each service to structure an upgradable and cost-effective service to attract more individuals in need of the service and attain a larger impact on the ear-and-hearing health care of the population. Stephens (2013) stated that while there are many considerations for providing services via tele-audiology, including its numerous limitations, its use can result in reliable and valid test results, extending to efficient provision of intervention and training (Khoza-Shangase et al. 2021). In tele-audiology, telecommunication technologies are utilised to access patients, assist practitioners in growing their practice reach, enhance patient access to specialists and satisfaction, prevent patients from having to trek long distances to access high-quality care and reduce practitioner isolation in rural areas (Krupinski 2015). These are recognisable benefits of tele-audiology in the African mining context, hence this chapter.

Because telehealth represents health care provision at a distance (Kim 2009), technological and connectivity advancements have assisted in bridging the gap between health care providers and their patients, thus surmounting geographical and economic hurdles that are a noteworthy challenge for the African context. Jacobs and Saunders (2014) argued that without question, tele-audiology has successfully prevailed over barriers such as shortage of specialist providers, cost and distance in remote settings to expand access to ear-and-hearing health care services. Ravi et al. (2018), recently reaffirmed by Khoza-Shangase et al. (2021) in a systematic review of telepractice and teletraining during the COVID-19 pandemic, argued that telehealth has also facilitated improved access to mentoring, supervision and professional training resources for health care professionals. Khoza-Shangase and Moroe (2020) suggested that this training, mentoring and supervision be extended to include training of non-professionals in task-shifting initiatives within the African context, a hybrid model of service delivery for preventive audiology recommended for the South African context by Khoza-Shangase and Sebothoma (2022). This hybrid model of service delivery includes the use of synchronous, asynchronous or hybrid tele-audiology, within programmatic approaches that utilise task-shifting to address the human resource challenge that prevails in the form of limited numbers of audiologists for the population needing services (Khoza-Shangase & Sebothoma 2022; Mulwafu et al. 2017; Ravi et al. 2018).

Krumm (2007) and Jacobs and Saunders (2014) reported that tele-audiology can be performed using at least four models of service delivery, with the hybrid model using a combination of these models also documented:

1. **Synchronous or real-time data collection, also called clinical video telehealth:** This model of service delivery permits real-time delivery, review and monitoring of clinical services using face-to-face videoconferencing between providers and their patients. In this synchronous model, real-time data collection can be utilised to perform audiological assessments, fitting of amplification devices and audiologist-driven real-ear measures, as well as tinnitus management and hearing aid orientation and counselling.
2. **Asynchronous or store-and-forward telehealth:** Asynchronous model utilises the store-and-forward approach, where the assessment findings are saved by a technician or patient-site facilitator at a remote facility and forwarded to a health care professional who reviews them later for analysis and diagnosis. This form of telepractice can be utilised for video otoscopy, pure tone and speech audiometry, acoustic immittance, OAEs and auditory-evoked potential readings such as auditory brain stem responses.

3. **Remote monitoring, also called home telehealth:** This model relies on the health care providers monitoring data collected by mobile devices. In audiology, remote monitoring can be utilised to monitor hearing changes longitudinally or to observe hearing aid use over time.
4. **Mobile health:** In this model, individuals, without the involvement of a practitioner, use smartphone applications (apps) or other software to manage their health conditions. Mobile health apps are available for tinnitus management, hearing aid orientation and counselling, hearing testing, auditory training, among others. Furthermore, there are also apps that can convert smartphones into high-level amplification or noise-monitoring devices.

Regardless of the model adopted, tele-audiology increases access to health care resources in a cost-efficient manner that can also serve as a supplement to face-to-face services (Fabry 2010; Maluleke et al. submitted), and this has been more clearly demonstrated in the COVID-19 pandemic era (Aggarwal et al. 2020; Fong et al. 2021; Khoza-Shangase 2022; Khoza-Shangase et al. 2021; Lam et al. 2021; Mansuri et al. 2021; McGill & Dennard 2021; Sebothoma et al. 2021). Within the South African mining industry, for example, Khoza-Shangase and Moroe (2020) strongly argued for tele-HCPs to be considered. In a scoping review, these authors justified careful consideration of telepractice in this sector because of the limited involvement of audiologists in ONIHL management through HCPs globally. Low-and-middle-income countries are hardest hit because of capacity versus demand challenges, where limited audiological services are available for the populations requiring them. The aim of Khoza-Shangase and Moroe's (2020) scoping review was directed by the question, 'Does tele-audiology have a potential value in HCPs, and what has been documented in the literature on the use of tele-audiology in HCPs?' This question was driven by the existing capacity versus demand challenges in Africa, and the researchers performed this scoping review to integrate available data for an evidence-mapping exercise that would facilitate the identification of gaps in the literature on tele-audiology and HCPs to inform research, policy formulation, practice and training – as recommended by Daudt, Van Mossel and Scott (2013) on the benefits of scoping reviews.

Findings of the review revealed that the use of tele-audiology within LMICs, and the African context in particular, is in its infancy, with limited evidence around ONIHL and HCPs. A significant paucity of evidence exclusive to the application of tele-audiology in the assessment and management of ONIHL, globally as well as locally, within the African context exists. This is notwithstanding the supposed potential value of this model of service delivery, especially in resource-limited settings such as in Africa. This scoping review failed to find a single publication that expressly studied or spoke to the application of tele-audiology in HCPs or ONIHL as its main focus. Refined analysis of publications deemed potentially relevant in this scoping review showed that in the past 10 years, at least five developments signal potential advancement in the application of tele-audiology in occupational audiology:

1. clinical guidelines and position papers on the need, application and potential value of tele-audiology in under-served communities
2. application of booth-less and wireless technology for industrial hearing assessments
3. performing pure-tone audiometry outside a sound booth utilising automation, earphone attenuation and integrated noise monitoring
4. diagnostic pure-tone audiometry without a sound-treated environment
5. utilisation of mobile technology for booth-less audiometry.

Khoza-Shangase and Moroe (2020) argued that all the publications in their scoping review reveal little to no evidence on all pillars of HCPs, except for indirectly addressing the audiometric evaluations pillar. The rest of the pillars on the hierarchy of control such as record-keeping; administrative and engineering controls; periodic noise exposure evaluation and monitoring; employee and management education, motivation and training; risk-based medical assessments and medical surveillance; as well as the use of personal hearing protection (Amedofu 2007; Hong et al. 2013) were not addressed in the evidence reviewed. These authors believe that all these pillars can incorporate tele-audiology within the African mining context, and they demonstrate this in a tele-HCP they recommend (Figure 10.1).

Chadambuka, Mususa and Muteti (2013, p. 899) maintained that 80% of individuals affected by ONIHL live in LMICs where ONIHL exerts a 'much heavier burden than in developed regions of the world'. Khoza-Shangase and Moroe (2020) highlighted that it is because of this reality that ONIHL is regarded as one of the biggest threats to a country's public health care system as well as its economy. Preventive audiology efforts to eliminate and or minimise ONIHL therefore have implications beyond the employee affected.

10.2. ONIHL and tele-audiology argued

On the inventory of work-associated morbidities, ONIHL has been ranked as number one and is second only to ARHL in the most frequent forms of acquired hearing loss (Mostaghaci et al. 2013; Ritzel & McCrary-Quarles 2008). Efforts towards curbing and or eliminating this occupational health condition need to be intensified. This increased focus is particularly important as Nandi and Dhatrak (2008) projected that ONIHL will secure more distinction as a significant public health care priority as populations begin to have longer lifespans in an increasingly industrialised world, thereby substantially contributing to the worldwide burden of this condition. Chapters 6 and 7 illustrate how the IR has seen increasing ONIHL in industries, while also demonstrating how this IR can be utilised to enhance OHS in mines. Within the African mining industry context, for example, the high burden of communicable diseases such as HIV, AIDS and TB, as well as the high occurrence of the risk factors for ONIHL as detailed in Chapters 3 and 9, significantly add to this public health care challenge.

Sufficient evidence has proven the significant implications of ONIHL for workers' safety, health, job performance, job security and career progression, as well as the general quality of life (Amjad-Sardrudi et al. 2012; Hong et al. 2013; Kane-Berman 2017; Picard et al. 2008; Si et al. 2020; Thorne 2006). Occupational noise-induced hearing loss has also been associated with undesirable outcomes for the economic forecast of both employers and employees (Chadambuka et al. 2013; Rikhardsson 2004; Yongbing & Martin 2013), with Yongbing and Martin (2013) proclaiming that ONIHL is a potentially expensive public health care challenge, particularly in LMICs. Hong et al. (2013) maintained that while the effects of ONIHL on an individual's health and quality of life are difficult to compute in concrete measures, compensation costs for claims related to ONIHL are steadily rising. In 2004, for example, the estimated total cost for occupational injuries and diseases was reported to range between 1% and 3% of the GDP in several countries (Rikhardsson 2004). This cost is significantly high for LMICs, although precise numbers on the burden of ONIHL in these countries are not instantly accessible (Nelson et al. 2005). Teke (2017) stated that in South Africa, the mining industry is one of the powerful pillars sustaining the country's economic and political development. The Chamber of Mines of South Africa (2013) affirmed that the South African mining sector is one industry that contributes substantially not only to the national economy but also to the economy of the entire African continent. Reports by the MCSA indicate that in 2019, the mining industry added R351 billion to the South African GDP in the year 2018. Africa's reported extractive commodities resource-abundant countries, such as Ghana, Mali and Tanzania, significantly contribute towards the African economy with extractive industries comprising two-thirds of Africa's exports (Chuhan-Pole, Dabalen & Land 2017). This evidence highlights how ONIHL therefore has a significant impact beyond the worker affected, thus the value of HCPs in African mines.

10.2.1. Clinical guidelines and position papers on the need, application and potential value of tele-audiology in under-served communities

All research conducted on the application of tele-audiology produces evidence that can guide evidence-based practice in audiology. However, such evidence is reinforced by endorsed position papers and clinical guidelines that steer the audiology profession. However, as far tele-audiology is concerned, the prevailing evidence in HCPs is constrained to mainly one pillar of HCPs (audiometric evaluations), even in countries such as Zimbabwe, Tanzania and

Ghana (Amedofu 2007; Chadambuka et al. 2013; Musiba 2015; Mutara & Mutanana 2015). The clinical guidelines and position papers reviewed in Khoza-Shangase and Moroe's (2020, p. 6) scoping review do not explicitly address tele-audiology in the context of occupational audiology. These authors bemoaned this as a serious limitation of these position papers and guidelines, because the occupational audiology context is a context that encompasses numerous factors that compel thoughtful reflection, and these include (1) litigation risks associated with occupational incident claims for ONIHL, thus the value of reliable and valid assessment measures that can stand up to legal scrutiny, over and above guiding clinical management; (2) capacity versus demand challenges as far as availability of audiologists who practise in occupational audiology; and (3) the type of the service needed (HCPs with specific pillars).

Audiology Australia (2015) provided a position paper as a reply to the Medicare Benefits Schedule (MBS) Review Taskforce's Consultation Paper, where they argued for tele-audiology's inclusion as it is expected to influence future audiological practice by altering the way clinical care services are delivered to rural areas of Australia. Audiology Australia maintains a position that telepractice is a suitable service delivery model for the Australian audiology profession. This position paper has important implications, for example, for the South African context's medical insurance coverage of services rendered via tele-audiology should its application become widely adopted. This includes, within occupational audiology, an issue that South African health care has not addressed in both regulations and clinical practice (Khoza-Shangase & Sebothoma 2022). Along with other challenges such as licensure, certification, quality control and jurisdictional responsibility within the South African context, Swanepoel et al. (2010) warned about reimbursement uncertainties related to tele-audiology. These authors raise a need for careful attention to be paid to these challenges for the successful implementation and sustainability of tele-audiology.

For the continent to efficiently address the aforementioned challenges, legal and policy provisions need to be promulgated. Siegfried, Wilkinson and Hofman (2017) raised the fact that South Africa, for instance, has lagged in its development of health technology assessment (HTA). These authors reported that no specific provision about legal and policy frameworks surrounding HTA is made in the *National Health Act 61 of 2003* and that HTA is currently narrowly and only partly described (Siegfried et al. 2017). Such an omission implies that there is currently minimal or no agreement on a suitable and beneficial definition of HTA appropriate for the South African setting and that legislative and policy requirements for a national HTA agency or an alternative instrument still need to be established (Khoza-Shangase & Moroe 2020). Siegfried et al. (2017) recommended that the policy and legal provisions noted should take into consideration the revision of relevant national policy and legislation to line up with the forthcoming South African National Health Insurance plan (NHI). Khoza-Shangase and Moroe (2020) suggested that now is the fitting time to also put forward deliberations around tele-audiology as a service delivery model in occupational audiology by the South African audiology community. Similar exercises can be conducted in the rest of the continent.

10.2.2. Application of booth-less and wireless technology for industrial hearing assessments

In line with Norris et al.'s (n.d.) findings, similar positive outcomes on the application of wireless and booth-less technology for hearing assessment in industry were found by Meinke et al. (2017). Comparable outcomes with the application of innovative, mobile wireless automated hearing-test system (WAHTS) in occupational audiometry, and valid thresholds were found in diverse assessment settings where sound-attenuating booths were not utilised. This study was aimed at evaluating test-retest variability of hearing thresholds measured through WAHTS with enhanced sound attenuation to assess noise-exposed workers at a worksite, as compared to standardised automated hearing thresholds measured in a mobile trailer sound booth. Because of the costs and the inconvenience linked to hauling mobile trailer booths from mine to mine, a current common practice where occupational audiometry is performed in African mines, Meinke et al.'s (2017) findings have relevant implications for the performance of audiometric evaluations as one of the key pillars of HCPs (Hong et al. 2013) across the continent.

10.2.3. Performing pure-tone audiometry outside a sound booth utilising automation, earphone attenuation and integrated noise monitoring

Investigations have been conducted to study the validity of diagnostic pure-tone audiometry in a natural environment utilising a computer-operated audiometer with insertable earphones covered by circum-aural earcups incorporating real-time monitoring of environmental noise (Maclennan-Smith, Swanepoel & Hall 2013). Findings from these studies have revealed that audiometry results obtained through this method of testing with recently developed technology are valid and reliable. Such findings, again, while considering the African context and its realities, raise numerous possibilities for increasing access to not only screening audiometry but diagnostic testing in populations such as the African mining industry, where sound-treated booths may not be easily accessible. The automated aspect of Maclennan-Smith et al.'s (2013) study has important implications for audiometric evaluations through tele-audiology in HCPs, as it studied the validity of an automated mobile diagnostic audiometer with increased attenuation and real-time noise monitoring for clinical testing outside a sound booth. In their investigation, these investigators discovered that air-conduction thresholds agree within 0 dB to 5 dB in 95% of all comparisons between the two test conditions, and bone-conduction thresholds also agreed similarly in 86% of comparisons. Similar findings have been obtained in nonoccupational audiometry contexts such as schools (Mahomed-Asmal, Swanepoel & Eikelboom 2016; Swanepoel, Maclennan-Smith & Hall 2013), highlighting the validity of this assessment method as part of tele-audiology within the African mining industry.

10.2.4. Diagnostic pure-tone audiometry without a sound-treated environment

When evaluating the validity of an automated mobile diagnostic audiometer during the measurement of pure-tone audiometry outside a sound booth using earphone attenuation, integrated noise monitoring and automation, Swanepoel et al. (2015) also established reliable air and bone-conduction hearing thresholds. In this study, which was aimed at investigating the validity of an automated mobile diagnostic audiometer with increased attenuation and real-time noise monitoring for clinical testing outside a sound booth (KUDUwave), 23 normally hearing adults and a subgroup of 11 control participants were tested to establish test-retest reliability. The outcomes of the study demonstrated valid environmental noise monitoring and enhanced passive attenuation of the KUDUwave. Furthermore, air-conduction thresholds in and outside the soundproof were found to be within 5 dB or less of each other over 90% of the time, and bone-conduction thresholds performed similarly 80% of the time between test conditions. Threshold differences were found to be statistically nonsignificant. Swanepoel et al.'s (2015) findings added to the evidence supporting tele-audiology use within the African mining industry, with a continued need for research in this context to confirm validation of these measures. Dietz (2019) raised caution about specificity, sensitivity and validation in his reflections on technological innovations around mobile Internet, smartphones and tablets. These innovations have facilitated the development of commercially available tablet audiometers that are viewed as the future in HCPs. Dietz's (2019) caution should be heeded in the context of this chapter.

10.2.5. The utilisation of mobile technology for booth-less audiometry

The use of mobile technology, such as the Internet, for booth-less audiometry has been found to be practicable, with Norris et al. (n.d.) highlighting that this is conceivable if ambient noise can be successfully controlled. This is the rationale for Khoza-Shangase and Moroe's (2020) suggestion of the relevance of studies investigating booth-less audiometry in South African mines for HCPs purposes. In LMIC contexts like the African context, where accessibility to audiometry has been severely influenced by the costs associated with procurement of sound booths (Brennan-Jones, Eikelboom & Swanepoel n.d.), over and above the capacity versus demand challenges of audiology (Moroe & Khoza-Shangase 2018; Mulwafu et al. 2017; Pillay et al. 2020), the application of mobile technology for booth-less audiometry should be intensely pursued. Findings were positive from two of Norris et al.'s (n.d.) studies that evaluated a prototype noise-attenuating wireless audiometric headset that pairs with a mobile device to conduct automated audiograms. These findings indicated that performing audiometry using Internet technologies is feasible if ambient noise is effectively managed. Within HCPs pillars, mines already have noise level measurements and monitoring tools, as well as engineering controls, to manage noise from the source, so keeping ambient noise levels controlled during this type of tele-audiology should not be a significant or insurmountable challenge.

10.3. Tele-HCP recommendation

Even though the incidence of ONIHL has been reported to be declining or at least remaining the same in HICs because of technological advancements that have facilitated investments into *buying quiet* by these countries (Morata & Meinke 2016; Safe Work Australia 2010), such developments have not been observed to transfer to similar investments in HCPs in Africa (Moroe et al. 2018; Moroe & Khoza-Shangase 2020). Although Africa has been implementing HCPs (Moroe et al. 2018; OSHA 2002), ONIHL continues to be recorded as a prevalent occupational health condition in the mining industry (Amedofu 2007; Chadambuka et al. 2013; Khoza-Shangase, Moroe & Edwards 2020; Moroe et al. 2018; Musiba 2015; Mutara & Mutanana 2015; WHO 2018b). For example, the South African MHSC aims towards *buying quiet,* which has been recognised to be an important ingredient to successful HCPs globally. This position is particularly important to this industry as this Council states one of its goals as 'every mineworker returning from work unharmed everyday: striving for zero harm' (MHSC 2015). Despite this positive ambition by the MHSC, evidence suggests that almost 73.2% of South African mineworkers are exposed to hazardous occupational noise levels surpassing the legislated exposure limit of 85 dBs, in the presence of HCPs (Edwards et al. 2011; Grobler et al. 2020; Moroe et al. 2020; Strauss et al. 2012), with numerous reviewed African context studies revealing minimal, if any, positive outcomes of HCPs (Amedofu 2002, 2007; Edwards & Kritzingert 2012; Grobler et al. 2020; Khoza-Shangase et al. 2020; Moroe et al. 2018; Musiba 2015; Mutara & Mutanana 2015; Ntlhakana et al. 2021; Zungu et al. 2015).

The lack of successful outcomes with HCP within the African mining context can be explained by numerous reasons, one of which is the minimal role played by audiologists in the mining industry. This limited involvement by audiologists is regardless of the American Academy of Audiology's (1997) mandate and the (HPCSA 2012) regulations that specify that audiologists should be the primary advocates for and the principal supervisors of HCPs. The prevailing shortage of audiology human resources impedes this profession's ability to accomplish its roles in all contexts within its scope of practice in the African context generally but more so in the mining sector (Khoza-Shangase 2021; Mulwafu et al. 2017; Pillay et al. 2020).

Khoza-Shangase (2021) detailed how capacity versus demand challenges are significantly felt in the provision of audiology services in South Africa, but worse so in non-traditional spaces of practice for audiology, such as occupational audiology. With only 157 hearing aid acousticians, 1589 speech therapists and audiologists and 642 audiologists registered with the HPCSA in 2018 to provide clinical services to a population of approximately 55 million South Africans, a significant capacity versus demand quandary exists. This challenge is less observed in the better-resourced private health care sector that provides health care to less than 20% of the country's total population – with the rest requiring state-funded health care in the public health care sector. An analysis of the geographic location of the registered audiologists indicates that the audiologists are least found in the four main South African provinces where the mining industry is mainly located – Northern Cape (7), North West (8), Limpopo (17) and Mpumalanga (38). These sparse numbers clearly illustrate the recognisable need for tele-audiology for the implementation and monitoring of HCPs. However, the role of the audiologists in HCPs must be reviewed to become more centrally located than the current peripheral positioning, if there is even a role. The role played by the negligible number of audiologists currently involved in HCPs in South African mines was found to be misaligned to their scope of practice, juniorised and devalued, with very limited scope (Moroe & Khoza-Shangase 2018). Khoza-Shangase and Moroe (2020) believed that this minimal involvement of audiologists in South African mines is arguably because of the reality that the role of audiologists has been minimised in the South African Department of Labour regulations on ONIHL, with occupational health officers and otorhinolaryngologists being prominently placed in the assessment and management of ONIHL (Department of Labour 2019).

In reviewing HCPs with the hierarchy of control pillars, the authors of this chapter strongly recommend that intensified considered actions be discussed by the African audiology community on the application of tele-audiology as an alternative and or interim service delivery model for the much-needed HCP services in this population. The current authors recommend that the African audiology community prepares for structured, systematic and sustainable application of tele-HCPs, once HTA regulations and policies are in place. The tele-HCP implementation options, as depicted in Figure 10.1, can serve as a guide to ensure coverage of all pillars in any African mine (Khoza-Shangase & Moroe 2020).

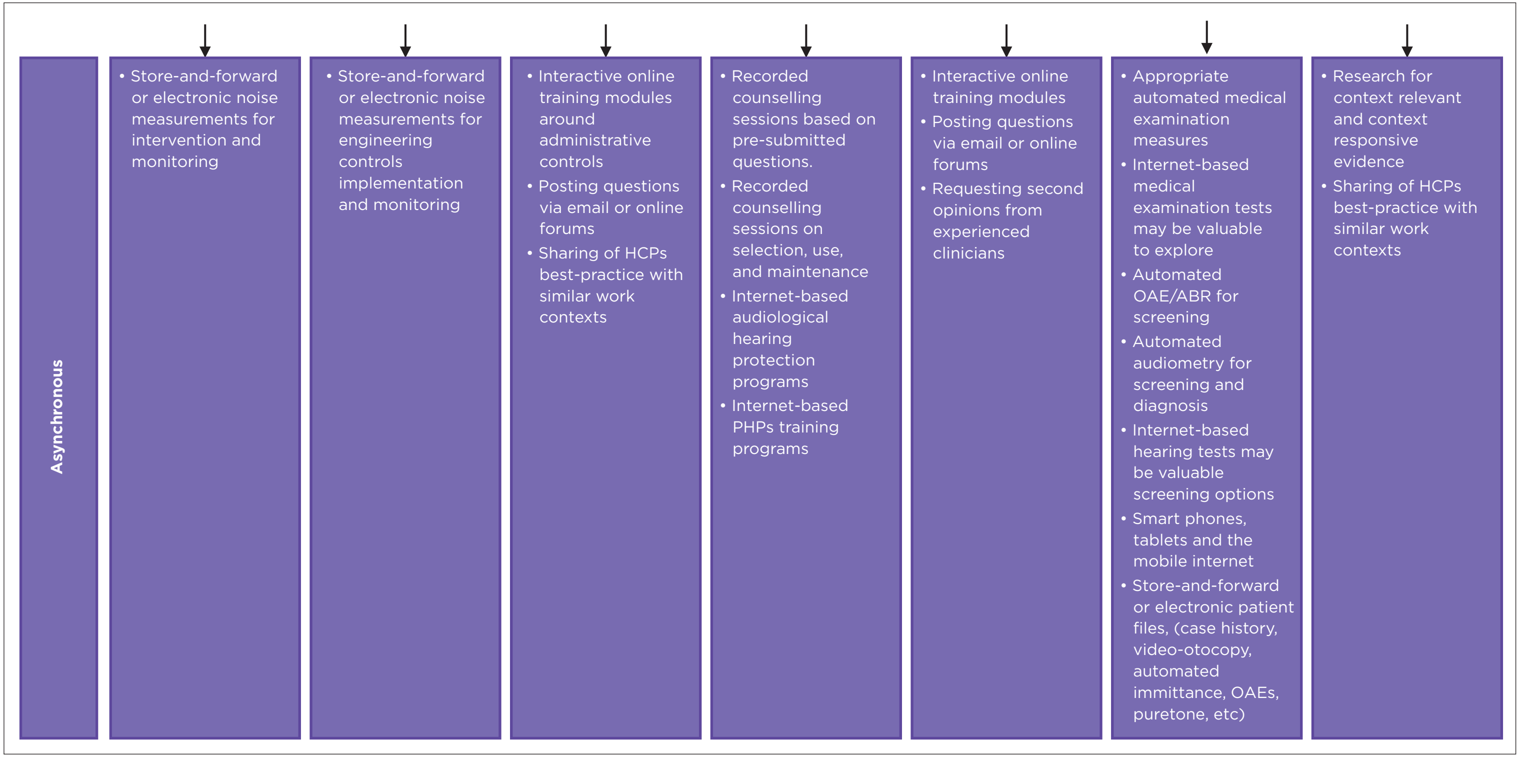
Figure 10.1 recommends ways in which all the pillars of HCPs could be operated and managed through tele-audiology application. This proposal requires a thorough analysis of all the depicted pillars, with the collation of data on the efficacy as well as ethical standards of tele-audiology within each pillar. The proposal also requires adherence to minimum standards and professional regulations, as well as scopes of practice, as advocated and promulgated by the relevant country's regulatory authority, such as the South African Department of Labour and HPCSA in the case of South Africa. Adherence to set regulations and observing minimum standards during service provision utilising tele-audiology in this area of practice is especially vital because nonaudiologists, including occupational nurses, paraprofessionals or trained volunteers, will be needed to serve as industrial-site facilitators who will be located remotely to the audiologist who will be the HCP manager, regardless of the type of tele-audiology being applied (Khoza-Shangase 2022). The recommended efficacy studies of tele-audiology as a tele-HCP approach would facilitate the implementation of intervention methods that are best practice because they will be guided by an evidence base that is contextually relevant to the South African mining context.

10.3.1. Considerations to keep in mind

For tele-audiology to be applied efficiently in any context, but more so in the African mining context, there are several considerations the occupational health team must bear in mind. Firstly, Audiology Australia (2020) asserted that while tele-audiology has the potential to change existing service delivery methods and the opportunity to provide audiology services to those who would otherwise not have access to them, such as HCPs as argued for in this chapter, issues concerning its sustainability need careful identification and documenting. Psarros and McMahon (2015) and Rushbrooke (2015) reported on five barriers to the sustainability of tele-audiology as a model of service delivery: (1) organisational attitudes, (2) consumer choice, (3) reimbursement issues, (4) equipment costs and (5) access to remote site to deliver services. Although specific to the South African context, Naudé and Bornman (2021) raised additional barriers to tele-audiology from the ethical perspective that can be applied throughout the continent, and these include the utilisation of support staff (facilitators), as well as key professionals' challenges such as informed consent, privacy, competence and standard of care. These barriers need careful deliberation when planning tele-audiology services within the African mining industry.

Tele-Hearing conservation programme (Tele-HCP)

Pillar	**Periodic noise exposure measurement/ monitoring**	**Engineering controls**	**Administrative controls**	**Personal hearing protection**	**Employee/ management education, motivation and training**	**Risk-based medical examination, medical surveillance and audiometric evaluations**	**Record-keeping**
Synchronous	• Real-time noise exposure measurements/ monitoring directed via videoconferencing and application sharing • Quality control of noise exposure measurements/ monitoring via interactive videoconferencing	• Real-time engineering controls and quality control of engineering controls via videoconferencing. • (E.g. monitoring of equipment or machinery maintenance, equipment replacement, isolating or enclosing the noise source, room treatments) • Real time recommendations around modifications or replacement of equipment, or recommendations around making related physical changes aimed at reducing the noise level at the worker's ear via interactive videoconferencing	• Real-time interactive videoconference presentations and engagements with employers around policy and regulations developments regarding employment measures to reduce worker exposure to excessive noise • Telementoring and guidance around rotating workers through jobs where excessive noise is present, (creating a work pattern where no employee is exposed to an eight-hour, time-weighted average in excess of 90 dB), increasing the distance between the worker and the source of the noise.	• Real-time interactive videoconference presentations and demonstrations on PHP (selection, use, and maintenance) • Telementoring and guidance during selection, fitting and use of PHPs. • Counselling and troubleshooting PHPs and their use via interactive videoconferencing • Custom PHPs fitting guided via interactive videoconferencing by an audiologist	• Real-time interactive videoconference presentations • Telementoring and guidance during assessments or procedures • Discussing difficult results/cases with experienced clinicians • Paper ward rounds cases of requiring diagnostic assessments and medical surveillance – and possible claims	• Real-time screening and diagnostic assessment directed via videoconferencing and application sharing • Quality control of screening and diagnostic assessment via interactive videoconferencing • Real-time medical/ audiological examinations/ assessments directed via videoconferencing and application sharing • Audiology directed by an audiology – case history, video-otoscopy, immittance, OAE, pure tone audiometry, AEPs, etc • Quality control of the medical examination via interactive videoconferencing	• Real-time record-keeping of all components of HCPs directed via videoconferencing and application sharing • Quality control of all records via interactive videoconferencing • Real-time proactive use of data for effective HCP implementation



Asynchronous	• Store-and-forward or electronic noise measurements for intervention and monitoring	• Store-and-forward or electronic noise measurements for engineering controls implementation and monitoring	• Interactive online training modules around administrative controls • Posting questions via email or online forums • Sharing of HCPs best-practice with similar work contexts	• Recorded counselling sessions based on pre-submitted questions. • Recorded counselling sessions on selection, use, and maintenance • Internet-based audiological hearing protection programs • Internet-based PHPs training programs	• Interactive online training modules • Posting questions via email or online forums • Requesting second opinions from experienced clinicians	• Appropriate automated medical examination measures • Internet-based medical examination tests may be valuable to explore • Automated OAE/ABR for screening • Automated audiometry for screening and diagnosis • Internet-based hearing tests may be valuable screening options • Smart phones, tablets and the mobile internet • Store-and-forward or electronic patient files, (case history, video-otocopy, automated immittance, OAEs, puretone, etc)	• Research for context relevant and context responsive evidence • Sharing of HCPs best-practice with similar work contexts

Key: ABR, auditory brainstem response; AEPs, auditory evoked potentials; HCPs, hearing conservation programmes; OAE, otoacoustic emission; PHP, personal hearing protection.
Source: Khoza-Shangase and Moroe (2020, p. 8).

FIGURE 10.1: Possibilities of tele-audiology use in hearing conservation programmes for all pillars (telehearing conservation programmes).

Secondly, well-recognised linguistic and cultural diversity challenges that present as barriers to service delivery, particularly within the South African SLH professions, do not automatically get resolved by ICT in tele-audiology. However, these barriers can be significantly lessened if addressed innovatively and deliberately (Khoza-Shangase 2022). The Ida Institute (2019) advocated that all audiological services should be delivered in a person-centred fashion, where the patient's preferences and values are respected, their family and friends are involved and there exists shared decision-making and goal-setting, with the free flow of information prioritised. This approach is in line with the South African Health Department's principle of '*Batho Pele*' which advocates putting patients first. Audiology Australia (2020) argued that tele-audiology will manifest a transition from provider-centred health care towards preventive person-centred health care. As part of digital health technology, tele-audiology is seen as being responsive to the patient's location and needs and is practically and clinically effective, thereby achieving the ideal person-centred care. Appropriate and efficient use of family members who might serve, for example, as interpreters and as patient-site facilitators could facilitate interventions that could otherwise not have happened as transport costs would have prevented the family from accompanying patients to the audiologists' consulting rooms. Over and above allowing for person-centred care, Audiology Australia (2020) presented an additional benefit of tele-audiology that extends the successful person-centred model of care to include the capacity for people to self-manage. Taylor (2020) stated that self-management involves educating individuals on how to dynamically recognise problems and resolve challenges linked to their hearing loss. In this view, audiologists' primary role is to assist their patients to become more successful self-managers of their hearing condition. Given many of the factors related to the affordability and accessibility of ear-and-hearing health care and the poor social determinants of health in Africa, self-directed care that can be facilitated by tele-audiology can benefit from this model of service delivery (Taylor 2020).

Thirdly, the role of patient-site facilitators in tele-audiology has a substantial impact on the realisation and sustainability of the service delivery. Coco, Davidson and Marrone (2020) explored what makes tele-audiology able to improve access to hearing health care through overcoming the geographic gap between providers and patients, and the role of patient-site facilitators, otherwise referred to as telepresenters (McSwain et al. 2017), patient-site presenters (Waibel et al. 2017) or e-helpers (Grogan-Johnson et al. 2011). In most tele-audiology interactions and interventions, a facilitator is required at the venue where the patient is located to assist with numerous assessments and intervention-related tasks (hands-on aspects of procedures) that the audiologist is unable to perform from a remote location (Krumm 2016). Coco et al. (2020) conducted a scoping review on evidence surrounding patient-site facilitators in tele-audiology, distinguishing facilitators' training, responsibilities and their background. Findings from this study revealed that several different individuals (14) are utilised in the role of patient-site facilitator, including nurses, audiologists, students, technicians, physicians, community health care workers, researchers, village health workers, volunteers or community members, family members, community-based rehabilitation workers, psychologists, local health care professionals and local assistants. These facilitators engaged in a variety of unique tasks (57), including greeting and orienting the patient to the assessment or intervention space, as well as facilitating communication, obtaining patient consent, assisting with technology at the patient site, sanitising the testing area and general infection control, sending data to the remote site and assisting with audiology procedures such as placing headphones on the patient's head and performing the manual aspects of video otoscopy. There were subspeciality duties that were recorded to be performed by the facilitators as well, and these included audiology-related procedures such as assisting with conducting safety simulation stops in cochlear implant programming, skin preparation for auditory-evoked potentials electrodes and assisting with the Dix–Hallpike manoeuvre.

The challenge identified in this scoping review was that the largest number of studies that were included (*n* = 42) did not express details on the facilitators' training that they received, and where it was described, there was no homogeneity in terms of content, depth and breadth, as well as information on provider or deliverer of training. Coco et al. (2020) concluded that for success and sustainability of tele-audiology, more studies are still required on patient-site facilitators with regard to their background, responsibilities and their training. Such studies would be critical within the African context, as Khoza-Shangase and Sebothoma (2022) asserted that within the African context, tele-audiology can only succeed if utilised within a service delivery model that involves task-shifting and the use of paraprofessionals. This, therefore, requires that future research be conducted within this context to investigate the role that these paraprofessionals have and their precise impact on tele-audiology service delivery (Khoza-Shangase 2022). Coco et al. (2020) proposed that future investigations in this area include clear descriptions on who the patient-site facilitator is, including their training, duties and background to be able to analyse and record their impact on tele-audiology service delivery. Evidence from these investigations can be valuable in informing the training curriculum or regulations for this role in terms of minimum standards for training, education and supervision. Khoza-Shangase and Sebothoma (2022) recommended that minimum standards be established for task-shifting within tele-audiology in the South African context, with a standard curriculum that is regulated by the HPCSA to be able to guide the professions and protect the public.

Fourthly, knowledge, attitudes and perceptions of audiologists on tele-audiology as a service delivery model are important factors to bear in mind for widespread, successful and sustainable use of tele-audiology. In Eikelboom and Swanepoel's (2016) international survey of audiologists' attitudes towards telehealth, results revealed positive attitudes towards telehealth applications and technology associated with it. Despite this positive attitude, less than a quarter of the respondents in this study had actually delivered services in their practices via tele-audiology. The authors of this chapter contend that Eikelboom and Swanepoel's (2016) findings might be abysmal in Africa where connectivity and access to technology present additional challenges to the acceptance of this service delivery model, over and above provider attitudes. Khoza-Shangase and Moroe (2020) believed that these challenges will debilitate all efforts to expand access to ear-and-hearing health care services, particularly in the context of the recognised and well-documented capacity versus demand quandary within the South African occupational health context.

Ravi et al. (2018) maintained that knowledge and positive perception of audiologists will influence the uptake and success of tele-audiology practice. In a systematic review, these authors established that generally, audiologists have positive attitudes regarding acceptance of the application of tele-audiology. The evidence seemed to indicate that audiologists gained their knowledge on tele-audiology from in-service training (on the job), graduate studies, as well as from independently sourced continuing professional education programmes. Molini-Avejonas et al.'s (2015) review found that published evidence on the use of tele-audiology was mainly from the USA (32%) and Australia (29.1%), with this model of service delivery being used for assessment (36.9%) and intervention (36.9%) in these countries. This review highlighted that most of the evidence resolved that telehealth has an advantage over face-to-face clinical services, and this advantage was recently heightened by COVID-19. Molini-Avejonas et al. (2015) raised the need for audiologists to acclimatise to telehealth applications, with their findings highlighting that audiologists need to become aware of, familiar with and knowledgeable about the use of tele-audiology for diagnostic and intervention functions as well as for professional advancement initiatives. Within the South African context, audiologists' knowledge and positive attitudes towards tele-audiology need to be guaranteed by training institutions and continuing professional development providers. With the ever-increasing advances in telecommunications, Internet services and satellite communication, as well as the country's drive towards capitalising on the 4IR, tele-audiology is most likely going to become a key model of service delivery, particularly with the prevailing capacity versus demand challenges. Efforts need to be increased on the training of audiologists in telepractice, as well as on further development and advancement of the tele-audiology as a service delivery platform – including teletraining (Nagdee et al. 2022).

Fifthly, as far as technological limitations are concerned, particularly because tele-audiology significantly relies on ICT, these limitations pose a risk to the success and sustainability of this model of service delivery. Wolfgang (2019) highlighted that these technological limitations can be on both sides of the interaction and care continuum. During synchronous tele-audiology where the audiologist is physically present, albeit remotely, logistical challenges linked to the use of technology can exist. These logistical challenges can include:

1. Slow speed insecure Internet connection, which is a significant limitation as a secure, high-speed Internet connection is required so that the audiologist and patient sites can communicate without disconnection.
2. Because of lack of financial and physical resources, patients may not have access to ICT devices, reliable Wi-Fi or reliable and available high-speed Internet, and these are required for tele-audiology to occur.
3. Mobile clinic-driven tele-audiology requires high-speed Internet access (broadband Internet) across all corners of the country – lack of access to broadband Internet serves as a limitation to tele-audiology in that context.
4. Patient ease and comfort with the use of technology for them to access ear-and-hearing health care is important for tele-audiology to succeed, with self-driven models being recommended for those patients with a high level of comfort with technology.
5. Tele-audiology techniques that do not have any live patient interaction and rely on technology to be the audiologist's eye present a significant technological risk, where intervention can either be delayed or incomplete, thus negatively influencing intervention and health outcomes.

Wolfgang (2019) provided an example illustrating that in some cases, the eye of an experienced health care practitioner may be the difference in recognising a patient that does not simply require a hearing aid reprogramming but has an enlarging growth that is creating auditory damage.

Lastly, as far as regulations and or policies are concerned, Givens, Yao and Yao (2013) asserted that innovation, although sometimes disruptive, has the capability to expose a new population to a service or product that they previously had no access to, as seen with tele-audiology. The remote health care access capabilities brought by innovation also present disruption and interruption to the traditional health care practice. This disruption can include technology used, reimbursement practices and regulation or licensure. It can also include areas that require development, revisions or amendments to regulations and policies governing them. In a systematic review, Ravi et al. (2018) found that limitations in infrastructure, reimbursement and licensure pose barriers to tele-audiology, findings that are similar to those in Bush et al.'s (2016) study. Strategies aimed at alleviating these disruptions need exploring within the African context. Wolfgang (2019) highlighted that in addition to direct patient care concerns surrounding tele-audiology, it is important that practising audiologists be cognisant of regulations governing their practice as well as the patient privacy protection in their context. This author stresses that services provided via tele-audiology must adhere to the same regulations governing face-to-face services. Careful consideration of adhering to regulations, such as maintaining patient privacy, needs to happen in tele-audiology where a facilitator is used during remote service delivery. Within the African context, facilitators are and will most likely not be registered health care practitioners, and so they might pose a risk to patient privacy, unless standard protocols and minimum standards are implemented during training and practice, with appropriate country regulations and or policies established for task-shifting. Similarly, security risks relating to store-and-forward, remote monitoring, etc., need to be carefully addressed to ensure that patient privacy is maintained and information vigilance is in place in line with the PoPIA. Wolfgang (2019) suggested that ICT security be tightened, including ensuring that Internet network connections are secure and encrypted and that supplementary consent processes be explored. Within the African context, such consent must be informed consent, with the audiologists making certain that linguistic and cultural incongruencies and challenges between practitioners and patients have not influenced it.

■ 10.4. Conclusion

The current lacunae of evidence on the application of tele-audiology in the assessment and management of ONIHL globally signals a lost opportunity to expand access to ear-and-hearing health care services for this excessive noise-exposed population, particularly in the African context, where capacity versus demand challenges have been well documented. Furthermore, this lag in the use of, and research into, tele-audiology in this area of audiology scope of practice is a missed opportunity where technological developments that can be applied in the audiometric evaluation pillar of HCPs have been documented (Khoza-Shangase & Moroe 2020). This is also a missed opportunity when considering some of the IR advances presented in Chapter 6. Technological advances, with their counterpart contemporary advances in telehealth, have boosted possibilities for contextually responsive alternative service delivery models, such as tele-audiology in HCPs. As far as the audiometric evaluation pillar of HCPs is concerned, publication of clinical guidelines and position papers on the need, application and potential value of tele-audiology in under-served communities; the application of booth-less and wireless technology for industrial hearing assessments; the performance of pure-tone audiometry outside a sound booth utilising automation, earphone attenuation and integrated noise monitoring; and the utilisation of mobile technology for booth-less audiometry and hearing screening utilising mobile apps are advancements that have substantially expanded the audiology community's capacity to provide ear-and-hearing health care services to resource-limited and remote settings across the continent, such as the occupational setting within the African context – with the validity of these measures having been established not only for screening but for diagnostic assessments as well. Extension of tele-audiology services to all the other pillars of HCPs is a material opportunity that has the potential to be effectively utilised via all forms of telepractice synchronously and/or asynchronously. The tele-HCPs proposed in this chapter must take caution of the considerations to keep in mind detailed in the previous section. They must also take cognisance of policy and regulations challenges highlighted, with strict adherence to ethics, human rights and medical law.

Chapter 11

Best practice for hearing conservation programmes in Africa

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11.1. Introduction

A significant number of employees with ONIHL within the African context will continue to have their ear-and-hearing health care neglected until efficient and effective HCPs are implemented. These programmes should take careful cognisance of cohesive, systematic and comprehensive nationalised occupational health strategies that are contextually responsive and relevant (Moroe 2020; Moroe & Khoza-Shangase 2018; Seixas et al. 2012). The authors of this chapter fervently believe that ear-and-hearing as well as occupational health care practitioners (OHPs) in Africa bear the ethical responsibility to

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ensure that the rights of employees at risk and or exposed to hazardous noise levels are upheld through the best practice in HCPs.

The HCPs are CIs that recognise and acknowledge the complexity of ONIHL and are implemented within systems interacting in multiple layers involving various factors (Moroe 2020; Seixas et al. 2012). These CIs call for the audiology community to be alive to realistic and contextually relevant challenges, which, within the African context, require Afrocentric best-practice solutions (Khoza-Shangase 2022). Guided by the systems theory (Mele, Pels & Polese 2010), to be realistic about the implementation, monitoring and evaluation of outcomes of HCPs within the African mining context, this book has raised a call for a paradigm shift in ONIHL and HCPs in Africa. The book has advanced sufficient arguments and evidence that provide the OHPs, audiologists, in particular, who are involved in ONIHL and HCPs with questions and possible solutions for future practice in the African context. The book further provides practitioners with contextually relevant best practice, best practice that is multidisciplinary in nature and engages all stakeholders in all relevant sectors, with the goal of adoption of a *preventive* audiology approach to ONIHL, rather than the current *compensation-oriented* approach. This chapter deliberates on the future of HCPs within the African context, focusing on the next best practice that is guided by local evidence, local context and local policies, thus ensuring an Afrocentric contribution to the world of evidence.

11.2. Occupational noise-induced hearing loss in Africa

Globally, it is reported that over 2 million occupational accidents are recorded annually with approximately 6 000 employee deaths because of poorly implemented OHS regulations (International Labour Organization 2014; Liu et al. 2020). Besides the cost to human lives, these accidents also carry a significant cost to the employer and the economy of the company and country involved. The prevalence of work-related accidents has been reported to be highest in LMICs, while it is reportedly declining in HICs (Abdallah et al. 2020). However, globally, for example, the costs associated with nonfatal occupational accidents approximated 4% of the global GDP in 2014 alone (Liu et al. 2020). This substantial financial cost highlights the importance of OHS programmes that are aimed at curbing or eliminating these accidents. As one of the common and most neglected occupational health hazards in the workplace, ONIHL and its management via HCPs is not routinely or successfully controlled, and HCPs are not universally implemented, especially in the African context (Moroe et al. 2018).

Occupational noise-induced hearing loss is a major occupational hazard caused by excessive noise exposure, which is one of the most common occupational risk factors, among numerous other risk factors for OHL.

Evidence indicates that occupational noise exposure threatens the hearing of many employees and has numerous documented negative effects on health, including irritability, insomnia and fatigue (Chen, Su & Chen 2020). The negative impact of noise exposure on hearing function in the form of ONIHL has documented effects on the affected individual's communication ability, can impair cognition and personal attention (Basner et al. 2014; Masterson et al. 2016) and can also cause elevated levels of sadness, social stress, negative interpersonal relationships, poor confidence and diminished self-identity (Basner et al. 2014; Chen et al. 2020; Masterson et al. 2016). Lin (2012) also maintained that older individuals with mild hearing impairment have twice the risk of developing dementia, with this risk more than doubling (fivefold) where severe hearing loss occurs.

Occupational noise-induced hearing loss has been documented to have devastating effects, not only on the quality of life of the individual affected as presented but also on the country's economy and the State's socio-economic resources (Khoza-Shangase 2020b; Moroe 2018). Chapter 2 lists the following challenges as exacerbating the impact of ONIHL in South Africa: (1) the QBoD (Khoza-Shangase 2020a; Yerramilli 2015), (2) low education and literacy levels, (3) low salaries and (4) poor social determinants of health, in the face of poor OHS awareness. For the employee, the profound effects extend to their family, while they are also significant for the employer who incurs costs through various ways, including (1) compensation for OHS claims, (2) loss of productivity from health-related absenteeism and (3) loss of employees if an employee can no longer continue to work because of the ONIHL disability. As far as the socio-economic impact to the State is concerned, the provision of socio-economic grants for employees with ONIHL is an additional strain to the system, the pressure that can be avoided if effective HCPs are implemented. Moroe (2018) advanced some of these reasons why ONIHL is deemed one of the topmost threats to the country's public health care and economy, hence the importance of efficient HCPs.

Hearing conservation programmes, as an example of a CI in health care, carry increasing costs that have a significant impact on the quality and outcomes of ear-and-hearing health care for employees exposed to excessive hazardous noise, typical of complex health care interventions (De Jonge, Huyse & Stiefel 2006; Moroe & Khoza-Shangase 2022). Numerous studies from the African context signify gaps in HCPs' conceptualisation, planning, implementation and monitoring, thus leading to fragmented, incoherent and minimally successful management of ONIHL within this context (Amedofu 2007; Amedofu & Fuente 2008; Dekker et al. 2011; Edwards et al. 2011,2015; Edwards & Kritzinger 2012; Kahan & Ross 1994; Khoza-Shangase 2020a 2020b; Liu et al. 2020; Moroe 2018, 2020; Moroe et al. 2018 2019; Moroe & Khoza-Shangase 2018; Mutara & Mutanana 2015; Ntlhakana, Kanji &

Khoza-Shangase 2015; Ntlhakana, Khoza-Shangase & Nelson 2020a; Pillay 2020; Pillay & Manning 2020; Strauss et al. 2014).

In a special issue journal hosted by the *South African Journal of Communication Disorders*, titled ‘Occupational Hearing Loss in Africa: An Interdisciplinary View of the Current Status’ (Khoza-Shangase, Moroe & Edwards 2020), sufficient evidence was presented to support the call for a paradigm shift in HCPs for assessment and management of ONIHL in Africa. Such a paradigm shift requires acknowledgement of the complex nature of ONIHL as well as the complex nature of its intervention, if positive outcomes are to be achieved (Moroe 2018). Complex interventions, within the systems theory approach, demand a realistic approach towards conceptualisation, planning, implementation, evaluating and monitoring of the hierarchy of control pillars of HCPs (Moroe & Khoza-Shangase 2022). This approach is in line with Kuipers et al.’s (2011) definition of complexity in health care provision, where cognisance must be taken of the inevitable interaction between multiple factors, including task-related factors, patient or employee factors, health care practitioner factors, team factors, environmental factors and organisational factors. Chapter 1 presents these factors, offering examples of what constitutes each factor.

Hearing conservation programmes are interventions aimed at reducing or potentially eliminating hazardous occupational noise that exceeds legislated limits in the workplace, thus preventing ONIHL. With the history of HCPs spanning over two decades in South Africa, various strategies have been adopted to address the iniquitousness of excessive noise exposure in the workplace and its impact on the hearing function of workers. Occupational audiometry advances that indicate a clear paradigm shift from *compensation as a goal* via PLH (Edwards & Kritzinger 2012; Musiba 2020; Ntlhakana et al. 2020a) to *prevention as a goal* via STS (Attarchi et al. 2010; Musiba 2020; Ntlhakana et al. 2021) have been widely adopted, with South Africa having recently joined this approach (Booi 2020; Moroe & Khoza-Shangase 2020; Ntlhakana et al. 2021; Ntlhakana, Nelson & Khoza-Shangase 2020b).

Such advances in audiometry protocols adopted as part of HCPs signify the value of audiometry in the prevention, identification and diagnosis of ONIHL, over and above compensation. The developments also have significant implications for practice in HCPs and should consider potential changes associated with advances in clinical audiology service delivery models such as tele-audiology. Moreover, they should consider the impact of automation and digitalisation (as presented in ch. 7), to name a few important considerations. This audiometry aspect of HCPs has important propositions for all stakeholders, including both the employer and the employee; therefore, the critical role of audiologists in HCPs needs highlighting. A centrally located role of the audiologist in HCPs ensures that risk factors such as genetic, lifestyle and health factors are consistently and comprehensively considered in the HCP as this forms part of the audiologists' training and scope of practice. Furthermore, nuanced application and interpretation of audiometry to ensure that early detection of hearing changes is possible; for example, using OAEs as well as STS instead of PLH requires the audiologists' skills and knowledge. The use of PLH cut-offs as a trigger for intervention has been shown to miss ONIHL until the loss is at a moderate to severe degree range (Kew 2018; Ntlhakana et al. 2020a; 2020b). It is therefore important that the best available measures that can identify hearing loss early, such as ultrahigh frequency audiometry, over and above those already listed, are applied and or supervised by appropriately and adequately trained professionals – audiologists. Consideration of these factors during the implementation of HCPs in an African context is important for successful and sustainable preventive audiology action that is responsive to context.

Successful implementation of HCPs within the African context continues to be a significant challenge because of the various contextual realities that these programmes must contend with. These context-specific realities, such as those of the South African context covered in Chapter 2, call for collaborative engagement, planning, implementation and monitoring of HCPs by all relevant occupational health stakeholders, with audiologists being more centrally placed than they currently are. These contextual challenges have been grouped into six, and they include (1) the global economic collapse and its effect on global demand, (2) uncertainty surrounding regulations and legislation, (3) infrastructure challenges: ports, energy, transportation and water, (4) workforce uncertainty, (5) burden of disease and (6) licence to operate, environmental compliance obligations, illicit and unlicensed mining and local grassroots activism. Arguably, similar contextual challenges exist in the whole continent. The HCP team needs to be cognisant of these challenges as well as the mining industry's plans to address them. This is particularly important if these plans embed OHS as one of the core priorities in the African context. Thus, the conceptualisation, implementation and monitoring of HCPs should bear these in mind.

The central placement of audiologists within HCPs will be advantageous in resolving the following challenges confronting HCPs:

1. clarifying accountability roles in as far as government enforcement of HCPs as an OHS regulation between the departments of health and minerals and energy (labour)
2. incorporation and integration of all relevant risk factors in HCPs, such as the burden of disease, gender issues in mining, market, investment and policy challenges, general health care challenges and poor social determinants of health

3. consistent and continuous infusion of new knowledge and advances in audiology into HCPs to achieve the *preventive* instead of *compensation* goal
4. advocating for HCPs within the broader mining industry goals and challenges.

As reported by Nupen (2020) for the South African context, the prevailing challenges most pressing to the employer relating to legislation and regulations that govern the industry include (1) the recommended revisions to the regulations published in terms of the *Mineral and Petroleum Resources Development Act, 2002* (MPRDA) concerning retrenchments, (2) the publication of recommended guidelines for the relocation of communities nearby mines and (3) the already effective 'once empowered, always empowered' clause which is engrained in the newest published 2018 Mining Charter. Such employer challenges need to be identified for the rest of the countries in the continent so that solutions are responsive to each context.

Understanding these challenges is important for context-relevant and responsive HCP planning. The current authors believe that proper and comprehensive understanding of these challenges and infusing discussions around ONIHL and HCPs within deliberations around the aforementioned challenges is strategically wise and forward-thinking. Embedding ONIHL and HCPs as part of OHS in all discussions, planning and strategising around regulations and legislation in mining is key to efficacious and sustainable preventive programmes. Conscious updating of both preventive and treatment measures where recent advances exist as far as occupational health conditions are concerned – including ONIHL is also important. Such a strategy will not only ensure best practice in terms of OHS but also contribute towards (1) economic growth, (2) job creation that includes employee empowerment goals, diversifying skills and enhanced employee job performance and (3) poverty alleviation within an investment-competitive sector that is striving for growth (Mbazima 2020).

Given that HCPs are one of the key aspects of OHS within the African mining industry, it is important to consider the realities of the African mining industry so that implementation is contextually relevant and responsive. Specific initiatives that audiologists can be involved in directly linked to current mining industry goals include the following:

- As far as the burden of disease is concerned, audiologists are best placed to know which conditions and or treatments for conditions have an influence on ONIHL. Therefore, they would ensure that appropriate identification and management of the burden of disease conditions such as HIV, AIDS and TB occurs as part of HCPs. Chapter 2 suggests comprehensive and programmatic inclusion of HCPs in programmes aimed at addressing the key burdens of disease within the sector, guided by the available evidence on the influence of these conditions and their treatments on ONIHL. For efficient integration of the burden of disease and their treatments in a HCP, Ntlhakana et al. (2020b) recommended that comprehensive integrative PDMS that incorporate the medical surveillance data set of the miners' ages, occupations, noise exposure levels, as well as the burden of diseases and their treatments be utilised to allow for comparative analysis to be conducted.

- As far as plans to address the impact of the global financial crisis on global demand are concerned, discussion on the exploration strategy that includes geological and geoscientific solutions that are comparable to global best practice (Mbazima 2020) should see audiologists providing input on the procurement of exploration equipment that falls under *buying quiet.* Furthermore, this should see audiologists advocating for AI and full automation where noise cannot be minimised or eliminated.
- As far as regulatory and legislative uncertainty is concerned, centrally located audiologists should engage in the regulation and legislation development and promulgation processes. This is done with the goal of ensuring that relevant pillars of HCPs, such as engineering and administrative controls, are embedded in such processes.
- As far as infrastructural challenges confronting the mining industry are concerned, particularly electricity supply, the OHS team (which includes audiologists) should provide input, as these challenges would have significant influences on OHS programmes as well. In the HCPs' list of pillars, energy supply uncertainty would have a negative impact on periodic noise exposure measurement and monitoring, management and employee education, training and motivation, as well as on risk-based medical examination, audiometric evaluations and medical surveillance (Hong et al. 2013). Furthermore, all efforts towards automation and AI, as some of the strategies to enhance productivity while minimising injuries (ONIHL), would be negatively affected by energy supply uncertainty.
- Lastly, as far as challenges around labour uncertainty are concerned, Chapter 2 advances an argument that minimal prioritisation of OHS issues in the African mining industry presents as a significant threat, which preventable occupational health conditions such as ONIHL exacerbate. The side-lining of OHS issues in favour of labour efficiency (Cawood 2011) can be prevented by efficient OHS programmes, including HCPs. Efficient and effective OHS programmes, amidst addressing all other labour challenges, highlight the importance of all relevant stakeholders, including the audiologists. One of the key labour challenges that audiologists can lobby for and provide motivation for is the attraction and retention of scarce skills that will aid the industry in meeting OHS industry targets. For example, OHS personnel such as audiologists as well as trained task-shifters, who audiologists can train and manage to increase access to audiological services within a resource-constrained context through innovative service

delivery models such as the use of tele-audiology and task-shifting, are those with such scarce skills. The use of tele-audiology and teletraining will also facilitate continued service delivery even at times such as the current coronavirus disease 2019 (COVID-19) pandemic, where direct employee contact for HCP implementation is challenging (Khoza-Shangase, Moroe & Neille 2021).

As part of confronting realities of HCPs in African mines, contextually relevant risk factors need to be established and embedded in all OHS programme planning. Seixas et al. (2011) and Amjad-Sardrudi et al. (2012) supported the importance of establishing and understanding the pathogenesis or risk factors for ONIHL, as they believe that although ONIHL is a complex condition, it is preventable. Understanding the risk factors is crucial to the development of appropriate preventive measures. The contextualisation of the risk factors, which have been covered in detail in Chapter 3, allows for the African mining industry, audiology community and policymakers to channel their resources efficiently for preventive outcomes, particularly because of the known resource constraints under which the mining industry is operating. This channelling of resources should be for both future planning and reflection on the effectiveness of past interventions.

For future preventive programmes planning within African mines, careful cognisance of the multitude of risk factors for ONIHL is important if primary prevention is to occur. Primary prevention minimises the need for HCPs and or enhances their success. For example, in South Africa, over and above the QBoD that occurs concurrently with noise exposure, employees are simultaneously exposed to several stressors (Chen et al. 2020; Golmohammadi & Darvishi 2019) that include a variety of personal factors (e.g. age, gender, genetic background, smoking, medication and drugs and contextual diseases), physical factors (e.g. lighting, heat, vibration and cold), chemical agents (e.g. carbon monoxide [CO]), solvents, heavy metals and ototoxic chemicals) and occupational factors (e.g. workload and shift work). All these factors require controlling for successful outcomes of HCPs. Employees' exposure to one or a combination of these risk factors leads to poorer outcomes as far as occurrence of ONIHL and success or failure of HCPs within the African mining industry. Evidence indicating that the combined effect of these risk factors may have synergistic, additive, potentiation or antagonistic effects (Chen et al. 2020; De Jong et al. 2012; Golmohammadi & Darvishi 2019) requires careful consideration in planning, implementation and monitoring of HCPs within the African context, bearing in mind the prevalence and or incidence of these risk factors within the mining industry. In establishing the prevalence and or incidence of risk factors for ONIHL within African mines, the mining industry must also invest in investigations on identified gaps, including (1) establishing solid evidence within the African context on genetic factors as well as contextual diseases and their treatments and their influences on

ONIHL, (2) the impact of chemical agents that are most prevalent within the African mining context and (3) the physical factors such as heat, vibration and cold and their influence on ONIHL.

Sufficient global as well as emerging continental evidence is available that shows that ONIHL is influenced by the factors presented earlier (Amiri et al. 2015; Amjad-Sardrudi et al. 2012; Bowens 2018a, 2018b; Brits et al. 2012; Chen et al. 2020; Concha-Barrientos, Campbell-Lendrum & Steenland 2004; Khoza-Shangase 2020b). Some of these factors fall under the burden of disease umbrella, the quadruple burden that South Africa suffers from (WHO 2018). The impact of the burdens of disease on ONIHL and HCPs within the African mining industry needs careful investigating and characterisation. Specifically, the relationship of communicable diseases (HIV and AIDS and TB) to ONIHL, the relationship of noncommunicable diseases (e.g. mental illnesses, diabetes, hypertension and cardiovascular diseases and chronic lung diseases such as asthma and cancer) to ONIHL, as well as the relationship of injury and trauma to ONIHL need exploration. This exploration will allow for contextualised HCPs implementation. Collation of such evidence will facilitate appropriate and accurate risk–benefit evaluations of HCPs. Furthermore, it will enhance the ability to effectively utilise comprehensive and effective PDMS to achieve the preventive outcomes aimed for in this sector.

For appropriate risk–benefit evaluations, the comprehensive investigations that are recommended require that large sets of data be collected, captured and analysed appropriately. This should be done by utilising appropriate data record-keeping systems that are of value not only for efficient HCPs but also for research purposes whose evidence allows for evidence-based best practice within the African mines. Currently, the PDMS that is utilised in South African mines, for example, has been found wanting (Ntlhakana et al. 2020a, 2021), limiting its value to HCPs. Ntlhakana et al. (2020a) argued that an inclusive integrative data management programme that allows access to data from all pillars of an HCP for each employee, including all risk factors, is required.

■ 11.3. Approaches to HCPs in the context of LMICs

A clear and contextualised understanding of the complex nature of ONIHL and its complex causes and risk factors allows for assessment and intervention approaches that are contextually responsive and therefore more likely to be successful. This is where technological advances including the 4IR, automation and AI are considered. The civilisations and advances in technology, knowledge and science that have been brought by the IRs have important influences on HCPs. As comprehensively covered in Chapter 6, these developments have facilitated ground-breaking innovations and transitions from manual labour to powered machines, steam engines, mechanisation and, ultimately, easy access to the Internet, information technology and AI. Evidence suggests that with the commercial gains through opening doors to industries and employment prospects and capital investments globally, IRs have also introduced and exposed workers to OHS hazards, including ONIHL. As much as IRs have contributed towards ONIHL, efforts to protect workers from hazardous noise exposure have also been influenced by these revolutions. As such, the current 4IR has been argued to have brought about cost-effective and easily accessible hearing conservation strategies. These strategies need careful consideration within the African context, where significant advances that have been documented globally have not reached yet, with the IR still lagging even in general health care delivery. These strategies include the use of hearing protector device fit-testing, also referred to as field attenuation estimation systems, used to determine the effectiveness of a HPD for individuals when worn correctly (Biabani et al. 2017; Hager 2011). This strategy promotes the proper use of HPDs through Internet-based hearing acuity tests and hearing loss simulation. It includes an optical scanning device for silicone ear impressions using advanced digital imaging, 3D modelling with the advantage of a low-cost, high-speed processing ability (Brauch 2017). Another advancement is seen in the use of smartphones. These smartphones promote low-cost noise measurements through apps that can conduct direct measurements of A-weighted sound pressure level through the use of Bluetooth remote communication which can be linked to a dosimeter and sound level meters (Brauch 2017). The significant shift in methods and systems used in mining over the past 100 years, from manual to full automated systems, including advances in the use of AI, has had an impact on ONIHL and the preventive strategies in place in HCPs. The dynamics of change of machinery and transportation methods in the mines from manually operated systems to mechanisation, and finally to the development of fully automated machinery and transportation vehicles with AI, have been presented in Chapter 7. The authors of Chapter 7 argue that fully automated mines will result in mineworkers, both in surface and underground mining, having minimal interaction with the mining environment, leading to less exposure to hazardous noise levels, with a consequent reduction in the prevalence and or severity of ONIHL within this context. The chapter illustrates this with two case examples, SUGM in Mali, which is a fully automated mine, and the SSW mining company's initiatives in South Africa. In these mines, automation and preparation to automate the mining environment are being carried out in Africa, with the potential for enhancing the OHS of employees at the same time as maximising outputs for the mining industry. Chapter 7 uses a novel FBA that can be utilised in the transition period to automation to show that as the mining industry transitions to fully automated mining, fewer employees are exposed to hazardous occupational noise. Such advances require collaborative work between all HCPs stakeholders, including engineers.

South Africa is not too far behind in these new developments as automation has been introduced in the extraction of diamonds, coal and copper in some mining companies, as discussed in Chapter 7. Furthermore, the MHSC has collaborated with researchers and mining equipment manufacturers in identifying innovative ways of making automation and digitalisation to improve safety and efficiency as well as more accessibility in all mining sectors. These developments are anticipated to facilitate a transition to real-time information management systems, robotic technologies and IoT as standard operation in the mines. As such, the novel FBA discussed in Chapter 7 can facilitate the transition from manual to full automation in the African mining industry, which, if implemented successfully, will potentially eliminate ONIHL in this sector.

■ 11.4. Complexities of HCPs in Africa

For the next best practice in ONIHL and HCPs within the African context, it is important that the three contextually relevant complexities that have been identified in this book are carefully considered. These are HCPs in the context of OHS, HCPs in the context of burden of disease and HCPs in the context of tele-audiology in African mines. Although the use of tele-audiology has not been widely explored in the mining sector, the advent of COVID-19 has placed occupational audiologists in a unique and opportune position to provide tele-audiology and increase access to occupational audiology in the mining industry. Coronavirus disease 2019 has accelerated telepractice as a model of health care service delivery, and as such, Audiology Australia (2020) confirmed that potentially, tele-audiology can transform and sustain the provision of audiology services beyond COVID-19. This position requires innovative initiatives such as the use of mobile clinics (teleconferencing) and mobile apps, for instance (Wolfgang 2019). To implement these innovations there will be a need to invest in minimal equipment purchases and additional training in most existing practices. A benefit for audiologists is that they will be on the forefront of e-health and will be ahead as the world moves towards non-traditional, alternative and complementary methods of health care provision.

Chapter 10 presents tele-audiology potential in LMICs, with a discussion of the various types of tele-audiology than can be used either singly or in combination in African HCPs. A tele-HCP model is then proposed for audiologists working in occupational health, with considerations that need to be kept in mind while implementing tele-audiology within the African mining industry presented. This tele-HCP model covers all pillars of HCPs allowing for comprehensive implementation of the CI and adherence to international and national noise regulations. Khoza-Shangase et al. (2021) highlighted how the limited use of tele-audiology is a missed opportunity for expanding access to audiological services, both in training platforms and in clinical service provision. The authors of this chapter believe this to be true for the management of

ONIHL, particularly in Africa, where capacity versus demand challenges have been well documented. The limited application of tele-audiology in HCPs also missed the opportunities presented by technological advancements such as automation and AI with some of the IR advances presented in Chapter 6 that have significant value for HCPs. The application of booth-less and wireless technology for industrial hearing assessments; the performance of pure-tone audiometry outside a sound booth utilising automation, earphone attenuation and integrated noise monitoring; the conduction of diagnostic pure-tone audiometry without a sound-treated environment; the utilisation of mobile technology for booth-less audiometry; and hearing screening using mobile apps are developments that have changed the future of audiology, with their application up to the audiology community to take advantage of. For the next best practice in ONIHL and HCPs, research in context needs to be conducted to ensure reliability and validity within the African context. The aforementioned examples of advances are located within the audiometric evaluations and monitoring pillar of HCPs; however, expansion of the application of these advances as well as additional new developments in innovations towards HCPs must occur in all the other pillars under the hierarchy of control. This expansion and developments require focused and deliberate investments into research by African mines and university research units into occupational audiology.

11.5. Conclusion

The elimination of ONIHL within the mining industry, despite the HCPs in place, may not be possible and achievable within the African context in the near future; however, numerous recommendations and interim solutions are available from conceptualisation, implementation to evaluation and monitoring of CIs aimed at achieving zero harm for mineworkers. These recommendations require a concerted collaborative effort from all stakeholders, with capitalisation on recent advances in both assessment and management of ONIHL. For success, the implementation of recommendations requires sensitivity and responsiveness to the context, while maintaining best practice within the less-than-ideal resource-constrained context. Positive outcomes will benefit not only the employees but also the employers, the State and the country as a whole. Context-responsiveness calls for continuous research to build the evidence that will allow for relevant evidence-based interventions, with complexities around HCPs within the African context forming part of the deliberations and planning that incorporates technological advances and developments in industrialisation, automation and AI. Countries such as South Africa, Ghana, Tanzania and Zimbabwe are making strides towards establishing evidence, while significant gaps still exist in the rest of the continent.

References

Chapter 1

Amedofu, GK 2002, 'Hearing-impairment among workers in a surface gold mining company in Ghana', *African Journal of Health Sciences*, vol. 9, no. 1, pp. 91–97. https://doi.org/10.4314/ajhs.v9i1.30759

Amedofu, GK 2007, 'Effectiveness of hearing conservation program at a large surface gold mining company in Ghana', *African Journal of Health Sciences*, vol. 14, no. 1, pp. 49–53. https://doi.org/10.4314/ajhs.v14i1.30846

Amedofu, GK & Fuente, A 2008, 'Occupational hearing loss in developing countries', in B McPherson & R Brouillette (eds.), *Audiology in developing countries*, Nova Science Publishers, Inc, Hauppauge, New York, pp. 189–221.

Amiri, F, Zamanian, Z, Mani, A & Hasanzadeh, J 2015, 'Effects of combined exposure to noise, heat and lighting on cognitive performance', *Iran Occupational Health*, vol. 12, no. 5, pp. 10–20.

Amjad-Sardrudi, H, Dormohammadi, A, Golmohammadi, R & Poorolajal, J 2012, 'Effect of noise exposure on occupational injuries: A cross-sectional study', *Journal of Research in Health Sciences*, vol. 12, no. 4, pp. 101–104.

Audiology Australia 2020, *Teleaudiology: Position statement*, viewed 10 January 2021, <https://audiology.asn.au/Tenant/C0000013/AudA%20Position%20Statement%20Teleaudiology%202020%20Final(1).pdf>

Basner, M, Babisch, W, Davis, A, Brink, M, Clark, C, Janssen, S & Stansfeld, S 2014, 'Auditory and non-auditory effects of noise on health', *Lancet*, vol. 383, no. 9925, pp. 1325–1332. https://doi.org/10.1016/S0140-6736(13)61613-X

Bowens, A 2018a, *Evidence updates on risk factors for occupational noise-induced hearing loss (ONIHL) update 3: Genetic factors*, viewed 10 March 2020, <https://www.acc.co.nz/assets/research/63e6836c44/ONIHL-evidence-genetics.pdf>

Bowens, A 2018b, *Evidence updates on risk factors for occupational noise-induced hearing loss (ONIHL) update 1: Exposure to solvents with or without noise*, viewed 10 March 2020, <https://www.acc.co.nz/assets/research/23160770fb/ONIHL-evidence-solvents.pdf>

Brauch, R 2017, 'Tech advances are reinventing hearing conservation programs: Open your ears', *Industrial Safety and Hygiene News*, viewed 10 March 2020, <https://www.ishn.com/articles/105847-tech-advances-are-reinventing-hearing-conservation-programs>

Brits, J, Strauss, S, Eloff, Z, Becker, PJ & Swanepoel, DW 2012, 'Hearing profile of gold miners with and without tuberculosis', *Occupational and Environmental Medicine*, vol. 69, no. 4, pp. 243–249. https://doi.org/10.1136/oemed-2011-100106

Chadambuka, A, Mususa, F & Muteti, S 2013, 'Prevalence of noise-induced hearing loss among employees at a mining industry in Zimbabwe', *African Health Sciences*, vol. 13, no. 4, pp. 899–906. https://doi.org/10.4314/ahs.v13i4.6

Chen, KH, Su, SB & Chen, KT 2020, 'An overview of occupational noise-induced hearing loss among workers: Epidemiology, pathogenesis, and preventive measures', *Environmental Health and Preventive Medicine*, vol. 25, no. 1, pp. 1–10. https://doi.org/10.1186/s12199-020-00906-0

Concha-Barrientos, M, Campbell-Lendrum, D & Steenland, K 2004, *Occupational noise: Assessing the burden of disease from work-related hearing impairment at national and local levels*, Environmental Burden of Disease Series, No. 9, viewed 10 January 2021, <https://apps.who.int/iris/handle/10665/43001>

Datta, J & Petticrew, M 2013, 'Challenges to evaluating complex interventions: A content analysis of published papers', *BMC Public Health*, vol. 13, no. 568, pp. 1–18. https://doi.org/10.1186/1471-2458-13-568

De Jonge, P, Huyse, FJ & Stiefel, FC 2006, ‘Case and care complexity in the medically ill’, *The Medical Clinics of North America*, vol. 90, no. 4, pp. 679–692. https://doi.org/10.1016/j.mcna.2006.04.005

Dekker, JJ, Edwards, AL, Franz, RM, Van Dyk, T & Banyini, A 2011, ‘Meeting the milestones: Are South African small-to medium-scale mines up to the task?’, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 5, pp. 309–313. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532011001700002&lng=en&tlng=en

Dimitrieska, S, Stankovsk, A & Efremova, T 2018, ‘The Fourth Industrial Revolution: Advantages and disadvantages’, *Economics and Management*, vol. 14, no. 2, pp. 182–187.

Edwards, AL, Dekker, JJ, Franz, RM, Van Dyk, T & Banyini, A 2011, ‘Profiles of noise exposure levels in South African mining’, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 5, pp. 315–322. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532011001700003&lng=en&tlng=en

Edwards, AL & Kritzinger, D 2012, ‘Noise-induced hearing loss milestones: Past and future’, *South African Institute of Mining and Metallurgy*, vol. 112, pp. 865–869. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532012001000006&lng=en&nrm=iso

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’, *Occupational Health Southern Africa*, vol. 21, no. 1, pp. 11–17. http://reference.sabinet.co.za/document/EJC166085

Golmohammadi, R & Darvishi, E 2019, ‘The combined effects of occupational exposure to noise and other risk factors – A systematic review’, *Noise & Health*, vol. 21, no. 101, pp. 125–141. https://doi.org/10.4103/nah.nah_4_18

Hong, O, Kerr, MJ, Poling, GL & Dhar, S 2013, ‘Understanding and preventing noise-induced hearing loss’, *Disease-a-Month*, vol. 59, no. 4, pp. 110–118. https://doi.org/10.1016/j.disamonth.2013.01.002

International Labour Organization (ILO) 2014, *Safety and health at work: A vision for sustainable prevention*, viewed 10 January 2021, <https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_301214.pdf>

International Social Security Association (ISSA) 2014, *Towards a global culture of prevention: Working conditions have a major and direct impact on the health and well-being of workers*, viewed 16 July 2020, <https://web.archive.org/web/20141222194701/http://www.issa.int/topics/occupational-risks/introduction>

Jäntti, M & Cater-Steel, A 2017, ‘Proactive management of IT operations to improve IT services’, *JISTEM-Journal of Information Systems and Technology Management*, vol. 14, pp. 191–218.

Khoza-Shangase, K 2010a, ‘Is there a need for ototoxicity monitoring in patients with HIV/AIDS?’, *African Journal of Pharmacy & Pharmacology*, vol. 4, pp. 574–579.

Khoza-Shangase, K 2010b, ‘HIV/AIDS and auditory function in adults: The need for intensified research in the developing world’, *African Journal of AIDS Research*, vol. 9, no. 1, pp. 1–9. https://doi.org/10.2989/16085906.2010.484531

Khoza-Shangase, K 2011, ‘Highly active antiretroviral therapy: Does it sound toxic?’, *Journal of Pharmacy & Bioallied Sciences*, vol. 3, no. 1, pp. 142–153. https://doi.org/10.4103%2F0975-7406.76494

Khoza-Shangase, K 2017, ‘Risk versus benefit: Who assesses this in the management of patients on ototoxic drugs?’, *Journal of Pharmacy & Bioallied Sciences*, vol. 9, no. 3, pp. 171–177. https://doi.org/10.4103/jpbs.JPBS_17_17

Khoza-Shangase, K 2020a, ‘Hearing function of gold miners with and without a history of tuberculosis treatment: A retrospective data review’, *Brazilian Journal of Otorhinolaryngology*, vol. 86, no. 3, pp. 294–299. https://doi.org/10.1016/j.bjorl.2018.12.003

Khoza-Shangase, K 2020b, ‘Burden of disease: A scoping review of HIV/AIDS and TB in occupational noise-induced hearing loss’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a669. https://doi.org/10.4102/sajcd.v67i2.669

Khoza-Shangase, K 2022, ‘Occupational noise-induced hearing loss and preventive audiology: Using contemporary evidence to achieve zero ear harm in South African mines’, ed. K Khoza-Shangase, P*reventive audiology: An African perspective*, AOSIS Books, Cape Town, pp. 235–251. https://doi.org/10.4102/aosis.2022.BK209.12

Khoza-Shangase, K 2022, ‘In pursuit of increasing the application of tele-audiology in South Africa: COVID-19 puts on the alert for patient site facilitator training’, *South African Journal of Communication Disorders*, vol. 69, no. 2, a900. https://doi.org/10.4102/sajcd.v69i2.900

Khoza-Shangase, K & Masondo, N 2020, ‘What Are the current audiological practices for ototoxicity assessment and management in the South African healthcare context?’, *International Journal of Environmental Research and Public Health*, vol. 17, no. 7, a2613. https://doi.org/10.3390/ijerph17072613

Khoza-Shangase, K & Moroe, N 2020, ‘South African hearing conservation programmes in the context of tele-audiology: A scoping review’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a670. https://doi.org/10.4102/sajcd.v67i2.670

Khoza-Shangase, K, Moroe, N & Edwards, A 2020, ‘Occupational hearing loss in Africa: An interdisciplinary view of the current status’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Khoza-Shangase, K, Moroe, N & Neille, J 2021, ‘Speech-language pathology and audiology in South Africa: clinical training and service in the era of COVID-19’, *International Journal of Telerehabilitation*, vol. 13, no. 1, pp. 1–31. https://doi.org/10.5195/ijt.2021.6376

Kuipers, P, Kendall, E, Ehrlich, C, McIntyre, M, Barber, L, Amsters, D et al. 2011, *Complexity and health care: health practitioner workforce, services, roles, skills and training to respond to patients with complex needs*, Clinical Education and Training Queensland, Brisbane.

Le, TN, Straatman, LV, Lea, J & Westerberg, B 2017, ‘Current insights in noise-induced hearing loss: A literature review of the underlying mechanism, pathophysiology, asymmetry, and management options’, *Journal of Otolaryngology – Head & Neck Surgery*, vol. 46, no. 1, p. 41. https://doi.org/10.1186/s40463-017-0219-x

Masterson, EA, Bushnel, PT, Themann, CL & Morata, TC 2016, ‘Hearing impairment among noise-exposed workers – United States, 2003–2012’, *Morbidity and Mortality Weekly Report*, vol. 65, no. 15, pp. 389–394. https://www.jstor.org/stable/24858027

Metidieri, MM, Rodrigues, HF, Filho, FJ, Ferraz, DP, Neto, AF & Torres, S 2013, ‘Noise-induced hearing loss (NIHL): Literature review with a focus on occupational medicine’, *International Archives of Otorhinolaryngology*, vol. 17, no. 2, pp. 208–212. https://doi.org/10.7162/S1809-97772013000200015

Min, J, Kim, Y, Lee, S, Jang, TW, Kim, I & Song, J 2019, ‘The fourth industrial revolution and its impact on occupational health and safety, worker’s compensation and labor conditions’, *Safety and Health at Work*, vol. 10, no. 4, pp. 400–408. https://doi.org/10.1016/j.shaw.2019.09.005

Moore, GF, Audrey, S, Barker, M, Bond, L, Bonell, C, Hardeman, W, Moore, L, O’Cathain, A, Tinati, T, Wight, D & Baird J 2015, ‘Process evaluation of complex interventions: Medical research council guidance’, *BMJ (Clinical Research Edn.)*, vol. 350, a1258. https://doi.org/10.1136/bmj.h1258

Moroe, NF 2018, O*ccupational noise-induced hearing loss in South African large scale mines: From policy formulation to implementation and monitoring,* viewed 10 March 2019, <https://hdl.handle.net/10539/27177>

Moroe, N 2020a, ‘Occupational noise induced hearing loss in the mining sector in South Africa: Perspectives from occupational health practitioners on how mineworkers are trained’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a676. https://doi.org/10.4102/sajcd.v67i2.676

Moroe, N & Khoza-Shangase, K 2018a, ‘Research into occupational noise induced hearing loss in South African large-scale mines: Access denied?’, *F1000Research, AAS Open Research*, vol. 1, p. 4. https://doi.org/10.12688/aasopenres.12829.1

Moroe, N & Khoza-Shangase, K 2018b, ‘Management of occupational noise induced hearing loss in the mining sector in South Africa: Where are the audiologists?’, *Journal of Occupational Health*, vol. 60, no. 5, pp. 376–382. https://doi.org/10.1539/joh.2018-0020-OA

Moroe, N & Khoza-Shangase, K 2020, 'Recent advances in hearing conservation programmes: A systematic review', *South African Journal of Communication Disorders*, vol. 67, no. 2, a675. https://doi.org/10.4102/sajcd.v67i2.675

Moroe, NF & Khoza-Shangase, K 2022, 'Complexities with hearing conservation programmes in South African mines: Applying complex interventions theory', in K Khoza-Shangase (ed.), *Complexities and challenges in preventive audiology: An African perspective,* AOSIS Books, Cape Town, pp. 125–140. https://doi.org/10.4102/aosis.2022.BK311.08

Moroe, NF 2020b, 'Occupational noise-induced hearing loss in South African large-scale mines: Exploring hearing conservation programmes as complex interventions embedded in a realist approach', *International Journal of Occupational Safety and Ergonomics*, vol. 26, no. 4, pp. 753–761. https://doi.org/10.1080/10803548.2018.1498183

Moroe, NF, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise-induced hearing loss in the mining sector in Africa: a systematic review – 1994 to 2016', *Noise and Vibration Worldwide*, vol. 49, no. 5, pp. 181–191. https://doi.org/10.1177/0957456518781860

Moroe, NF, Khoza-Shangase, K, Madahana, MCI & Nyandoro, OTC 2019, 'A feedback-based noise-monitoring model: A proposed model of managing occupational noise induced hearing loss in the mining sector in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 119, pp. 671–679. https://doi.org/10.17159/24119717/18/016/2019

Moroe, NF, Khoza-Shangase, K, Madahana, MCI & Nyandoro, OTC 2020, 'Feedback-based noise management matrix in action', *South African Journal of Communication Disorders*, vol. 67, no. 2, a678. https://doi.org/10.4102/sajcd.v67i2.678

Mulwafu, W, Ensink, R, Kuper, H & Fagan, J 2017, 'Survey of ENT services in sub-Saharan Africa: Little progress between 2009 and 2015', *Global Health Action*, vol. 10, no. 1, a1289736. https://doi.org/10.1080/16549716.2017.1289736

Musiba, Z 2015, 'The prevalence of noise-induced hearing loss among Tanzanian miners', *Occupational Medicine*, vol. 65, no. 5, pp. 386–390. https://doi.org/10.1093/occmed/kqv046

Mutara, G & Mutanana, N 2015, 'An analysis of a hearing conservation programme (HCP) at a mining company in Zimbabwe', *Journal of Biology, Agriculture and Healthcare*, vol. 5, pp. 51–58.

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', *Occupational Health Southern Africa*, vol. 21, pp. 10–15.

Ntlhakana, L, Khoza-Shangase, K & Nelson, G 2020b, 'Occupational noise-induced hearing loss in platinum miners: What do the data tell us?', *Occupational Health Southern Africa*, vol. 26, no. 1, pp. 8–14. https://doi.org/10.17159/2411-9717/1318/2021

Ntlhakana, L, Nelson, G & Khoza-Shangase, K 2020a, 'Estimating miners at risk for occupational noise-induced hearing loss: A review of data from a South African platinum mine', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a677. https://doi.org/10.4102/sajcd.v67i2.677

Ntlhakana, L, Nelson, G, Khoza-Shangase, K & Dorkin, E 2021a, 'Occupational hearing loss for platinum miners in South Africa: A case study of data sharing practices and ethical challenges in the mining industry', *International Journal of Environmental Research and Public Health*, vol. 19, no. 1, a1. https://doi.org/10.3390/ijerph19010001

Ntlhakana, L, Nelson, G, Khoza-Shangase, K & Maposa, I 2021b, 'Predicting standard threshold shifts for occupational hearing loss among miners at a large-scale platinum mine in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 121, no. 8, pp. 397–404. https://doi.org/10.17159/2411-9717/1318/2021

Nupen, L 2020, *Mining in South Africa: Industry challenges in 2020*, viewed 10 January 2021, <https://www.miningreview.com/gold/mining-in-south-africa-industry-challenges-in-2020/>

Pillay, M 2020, 'Chemicals, noise and occupational hearing health in South Africa: A mapping study', *South African Journal of Communication Disorders*, vol. 67, no. 2, a693. https://doi.org/10.4102/sajcd.v67i2.693

Pillay, M & Manning, WG 2020, 'A critical analysis of the current South African occupational health law and hearing loss', *South African Journal of Communication Disorders*, vol. 67, no. 2, a694. https://doi.org/10.4102/sajcd.v67i2.694

Pillay, M, Tiwari, R, Kathard, H & Chikte, U 2020, ‘Sustainable workforce: South African audiologists and speech therapists’, *Human Resources for Health*, vol. 18, no. 1, pp. 1–13. https://doi.org/10.1186/s12960-020-00488-6

Seixas, NS, Neitzel, R, Stover, B, Sheppard, L, Feeney, P, Mills, D & Kujawa, S 2012, ‘10-year prospective study of noise exposure and hearing damage among construction workers’, *Occupational and Environmental Medicine*, vol. 69, no. 9, a64350. https://dx.doi.org/10.1136%2Foemed-2011-100578

South African Mine Health and Safety Council (MHSC) 2014a, *2014 MHSC Summit: every mine worker returning from work unharmed every day striving for zero harm*, Mine Health and Safety Council, viewed 15 December 2018, <https://www.google.com/search?q=2014+MHSC+Summit%3A+Every+mine+worker+returning+from+work+unharmed+every+day+striving+for+zero+harm.%2C+Mine+Health+and+Satfety+Council.&sxsrf=ALiCzsaapLCXHh-ZviTaRBukWymsaYjuKA%3A1657810382414&source=hp&ei=zi3QYtu-FoKWgQavrrfoDg&iflsig=AJiK0e8AAAAAYtA73j7sC7xbj03FCTwyD_EyL5VNJEg7&ved=0ahUKEwjb3cj30Pj4AhUCS8AKHS_XDe0Q4dUDCAc&uact=5&oq=2014+MHSC+Summit%3A+Every+mine+worker+returning+from+work+unharmed+every+day+striving+for+zero+harm.%2C+Mine+Health+and+Satfety+Council.&gs_lcp=Cgdnd3Mtd2l6EANQAFgAYMcFaABwAHgAgAEAiAEAkgEAmAEAoAECoAEB&sclient=gws-wiz>

South African Mine Health and Safety Council (MHSC) 2014b, ‘Every mine worker returning from work unharmed every day: striving for zero harm’, *paper presented at the proceedings of the 10th anniversary of the 2003 occupational health and safety milestones*, Woodmead, Johannesburg, 19–20 November 2014.

Strauss, S, Swanepoel, DW, Becker, P, Eloff, Z & Hall, JW 3rd 2014, ‘Noise and age-related hearing loss: a study of 40 123 gold miners in South Africa’, *International Journal of Audiology*, vol. 53, no. 2, pp. 66–75. https://doi.org/10.3109/14992027.2013.865846

Wade, VA, Eliott, JA & Hiller, JE 2012, ‘A qualitative study of ethical, medico-legal and clinical governance matters in Australian telehealth services’, *Journal of Telemedicine and Telecare*, vol. 18, no. 2, pp. 109–114. https://doi.org/10.1258/jtt.2011.110808

Wade, VA, Eliott, JA & Hiller, JE 2014, ‘Clinician acceptance is the key factor for sustainable telehealth services’, *Qualitative Health Research*, vol. 24, no. 5, pp. 682–694. https://doi.org/10.1177/1049732314528809

Wolfgang, K 2019, ‘Risks, rewards of teleaudiology’, *The Hearing Journal*, vol. 72, no. 1, pp. 28–30. https://doi.org/10.1097/01.HJ.0000552746.59241.4a

World Health Organization (WHO) 2001, *International classification of functioning, disability and health*, viewed 06 October 2019, <https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health#:~:text=ICF%20is%20the%20WHO%20framework,and%20measure%20health%20and%20disability>

World Health Organization (WHO) 2018, *Country cooperation strategy at a glance*, viewed 17 January 2021, <https://apps.who.int/iris/bitstream/handle/10665/136874/ccsbrief_zaf_en.pdf;jsessionid=E4076B95B82E47064DB7DB3E8F795799?sequence=1>

Zungu, LI, Edwards, AL, Milanzi, LA, Khoza, NN & Letsoalo, MS 2015, ‘Evaluation of the current practices of noise-induced hearing loss (NIHL) awareness training in the South African mining industry’, *Occupational Health Southern Africa*, vol. 21, no. 1, pp. 11–17.

Chapter 2

African Union (AU) 2016, *Africa health strategy 2016–2030*, viewed 16 March 2021, <https://au.int/sites/default/files/newsevents/workingdocuments/27513-wd-sa16951_e_africa_health_strategy-1.pdf>

Agwa-Ejon, JF & Pradhan, A 2018, ‘Life cycle impact assessment of artisanal sandstone mining on the environment and health of mine workers’, *Environmental Impact Assessment Review*, vol. 72, pp. 71–78. https://doi.org/10.1016/j.eiar.2018.05.005

Alli, BO 2008, *Fundamental principles of occupational health and safety*, International Labour Office (ILO), Geneva, viewed 16 March 2021, <https://www.ilo.org/global/publications/ilo-bookstore/order-online/books/WCMS_093550/lang--en/index.htm>

Amedofu, GK 2007, 'Effectiveness of hearing conservation program at a large surface gold mining company in Ghana', *African Journal of Health Sciences*, vol. 14, no. 1, pp. 49–53. https://doi.org/10.4314/ajhs.v14i1.30846

American Academy of Audiology 2003, *Position statement: Preventing noise-induced occupational hearing loss*, viewed 16 March 2021, <https://oem.msu.edu/images/newsletter/NowHearThis/Hv6n4.pdf>

American Speech-Language-Hearing Association 2004, *The audiologist's role in occupational hearing conservation and hearing loss prevention programs*, viewed 10 January 2021, <https://www.asha.org/policy/tr2004-00153/>

AngloGold Ashanti 2012, *Country fact sheet South Africa*, viewed 16 March 2021, <http://www.aga-reports.com/12/>

Beech, W 2014, 'Challenges faced by the South African exploration and mining industry', *Mining Review Africa*, viewed 08 June 2019, <https://www.miningreview.com/industry-insight/challenges-faced-by-the-south-african-exploration-and-mining-industry/>

Bhunu, CP, Mushayabasa, S & Smith, RJ 2012, 'Assessing the effects of poverty in tuberculosis transmission dynamics', *Applied Mathematical Modelling*, vol. 36, no. 9, pp. 4173–4185. https://doi.org/10.1016/j.apm.2011.11.046

Brits, J, Strauss, S, Eloff, Z, Becker, PJ & Swanepoel, DW 2012, 'Hearing profile of gold miners with and without tuberculosis', *Occupational and Environmental Medicine*, vol. 69, no. 4, pp. 243–249.

Cawood, FT 2011, 'Threats to the South African minerals sector: An independent view on the investment environment for mining', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 7, pp. 469–474. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532011000700006&lng=en&nrm=iso

Chaisson, RE & Martinson, NA 2008, 'Tuberculosis in Africa – Combating an HIV-driven crisis', *New England Journal of Medicine*, vol. 358, no. 11, pp. 1089–1092. https://doi.org/10.1056/NEJMp0800809

Chamber of Mines of South Africa 2013, *Annual report 2012/2013*, viewed 16 March 2021, <https://www.mineralscouncil.org.za/industry-news/publications/annual-reports/send/15-archived/133-annual-report-2012-2013>

Chamber of Mines of South Africa 2016, *Mining in South Africa: The challenges and the opportunities*, viewed 16 March 2021, <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiujb2f06zuAhVUQxUIHdZWDjQQFjAAegQIARAC&url=https%3A%2F%2Fwww.mineralscouncil.org.za%2Findustry-news%2Fpublications%2Fpresentations%2Fsend%2F7-2015%2F269-mining-in-south-africa-the-challenges-and-opportunities&usg=AOvVaw2toa_T6s33tEE1NQrfw2CF>

Chime, I 2019, *Top 10 African countries with the best education systems*, viewed 16 March 2021, <https://www.afterschoolafrica.com/42898/top-10-african-countries-with-the-best-education-systems/#:~:text=South%20Africa,with%20a%20score%20of%2058.4>

Churchyard, GJ, Corbett, EL, Kleinschmidt, I, Mulder, D & De Cock, KM 2000, 'Drug-resistant tuberculosis in South African gold miners: Incidence and associated factors', *The International Journal of Tuberculosis and Lung Disease*, vol. 4, no. 5, pp. 433–440. https://pubmed.ncbi.nlm.nih.gov/10815737/

Coleman, N 2012, 'More questions than answers', *Mail and Guardian*, viewed 13 November 2018, <https://mg.co.za/article/2012-11-02-more-questions-than-answers/>

Cornish, L 2020, *Where is the reference point for modernisation in the mining industry?*, viewed 18 March 2021, <https://www.miningreview.com/base-metals/where-is-the-reference-point-for-modernisation-in-the-mining-industry/>

Coulson, N 2018, 'The role of workplace health and safety representatives and the creeping responsibilisation of occupational health and safety on South African mines', *Resources Policy*, vol. 56, pp. 38–48. https://doi.org/10.1016/j.resourpol.2018.02.007

Cullinan, K 2018, 'R1.4 billion settlement for miners with silicosis', TB *Health24*, viewed 18 March 2021, <https://www.news24.com/health24/news/public-health/r14-billion-settlement-for-miners-with-silicosis-tb-20180508#:~:text=Mining%20is%20a%20hazardous%20occupation,mines%20from%2012%20March%201965>

Davies, H, Marion, S & Teschke, K 2008, 'The impact of hearing conservation programs on incidence of noise-induced hearing loss in Canadian workers', *American Journal of Industrial Medicine*, vol. 51, no. 12, pp. 923–931. https://doi.org/10.1002/ajim.20634

Dekker, JJ, Edwards, AL, Franz, RM & Banyini, A 2011, 'Meeting the milestones are South African small- to medium-scale mines up to the task', *South African Institute of Mining and Metallurgy*, vol. 111, no. 5, pp. 309–313. https://www.saimm.co.za/Journal/v111n05p309.pdf

Dlamini, L, Mququ, P & Hattingh, CST 2016, *Burden of health & disease in South Africa: Medical research council briefing*, Parliamentary Monitoring Group, viewed 24 March 2021, <https://pmg.org.za/committee-meeting/22198/>

Dobie, RA 2008, 'The burdens of age-related and occupational noise-induced hearing loss in the United States', *Ear and Hearing*, vol. 29, no. 4, pp. 565–577. https://doi.org/10.1097/AUD.0b013e31817349ec

Edwards, A & Kritzinger, D 2012, 'Noise-induced hearing loss milestones: Past and future', *Journal of the South African Institute of Mining and Metallurgy*, vol. 112, no. 10, pp. 865–869. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532012001000006&lng=en&nrm=iso

Edwards, A, 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', *Occupational Health Southern Africa*, vol. 21, no. 1, pp. 11–17. http://reference.sabinet.co.za/document/EJC166085

Grobler, LM, Swanepoel, W, Strauss, S, Becker, P & Eloff, Z 2020, 'Occupational noise and age: A longitudinal study of hearing sensitivity as a function of noise exposure and age in South African gold mine workers', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a687. https://doi.org/10.4102/sajcd.v67i2.687

Health Professions Council of South Africa (HPCSA) 2012, *Regulations relating to the undergraduate curricula and professional examinations in audiology*, viewed 13 July 2018, <https://www.hpcsa.co.za/Uploads/SLH/gg35350_nn387.pdf>

Hill, N & Maroun, W 2015, 'Assessing the potential impact of the Marikana incident on South African mining companies: An event method study', *South African Journal of Economic and Management Sciences*, vol. 18, no. 4, pp. 586–607. https://doi.org/10.17159/2222-3436/2015/v18n4a10

Hong, O, Kerr, MJ, Poling, GL & Dhar, S 2013, 'Understanding and preventing noise-induced hearing loss', *Disease-a-month: DM*, vol. 59, no. 4, pp. 110–118. https://doi.org/10.1016/j.disamonth.2013.01.002

Joint United Nations Programme on HIV/AIDS (UNAIDS) 2020a, *Global HIV & AIDS statistics – 2020 fact sheet*, viewed 05 March 2021, <https://www.unaids.org/en/resources/fact-sheet>

Joint United Nations Programme on HIV/AIDS (UNAIDS) 2020b, *Country fact sheets: South Africa, 2019*, viewed 05 March 2021, <https://www.unaids.org/en/regionscountries/countries/southafrica>

Kaggwa, M 2020, 'Interventions to promote gender equality in the mining sector of South Africa', *The Extractive Industries and Society*, vol. 7, no. 2, pp. 398–404. https://doi.org/10.1016/j.exis.2019.03.015

Kane-Berman, J 2017, 'Diamonds and all that: The contribution of mining to South Africa', in *Mining in SA: Then, now, and into the future – IRR*, viewed 16 March 2018, <https://www.polity.org.za/article/diamonds-and-all-that-the-contribution-of-mining-to-south-africa-2017-02-16>

Khalane, S 2011, 'Nationalisation will worsen brain drain', *Free State Times*, 24–30 June.

Khoza-Shangase, K 2019, 'Pharmaco-audiology vigilance in the treatment of patients with HIV/AIDS: Ototoxicity monitoring protocol recommendation', *Infectious Disorders – Drug Targets*, vol. 19, no. 1, pp. 1–9. https://doi.org/10.2174/1871526518666181016102102

Khoza-Shangase, K 2020a, 'Burden of disease: a scoping review of HIV/AIDS and TB in occupational noise-induced hearing loss', *South African Journal of Communication Disorders*, vol. 67, no. 2, a669. https://doi.org/10.4102/sajcd.v67i2.669

Khoza-Shangase, K 2020b, 'Hearing function of gold miners with and without a history of tuberculosis: treatment: A retrospective data review', *Brazilian Journal of Otorhinolaryngology*, vol. 86, no. 3, pp. 294–299. https://doi.org/10.1016/j.bjorl.2018.12.003

Khoza-Shangase, K 2021, 'Confronting realities to early hearing detection in South Africa', in K Khoza-Shangase & A. Kanji (eds.), *Early detection and intervention in audiology: An African perspective*, Wits University Press, Johannesburg, pp. 66–68.

Khoza-Shangase, K & Moroe, NF 2020a, 'Risk versus benefit: Should not audiologists assess this in the context of occupational noise-induced hearing loss in the mining industry?', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a671. https://doi.org/10.4102/sajcd.v67i2.671

Khoza-Shangase, K & Moroe, N 2020b, 'South African hearing conservation programmes in the context of tele-audiology: A scoping review', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a670. https://doi.org/10.4102/sajcd.v67i2.670

Khoza-Shangase, K, Moroe, N & Edwards, A 2020, 'Occupational hearing loss in Africa: An interdisciplinary view of the current status', *South African Journal of Communication Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Kistnasamy, B, Yassi, A, Yu, J, Spiegel, SJ, Fourie, A, Barker, S & Spiegel JM 2018, 'Tackling injustices of occupational lung disease acquired in South African mines: Recent developments and ongoing challenges', *Globalization and Health*, vol. 14, no. 1, p. 60. https://doi.org/10.1186/s12992-018-0376-3

Lane, A, Guzek, J & Van Antwerpen, W 2015, 'Tough choices facing the South African mining industry', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 115, no. 6, pp. 471–479. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532015000600006&lng=en&tlng=en

Lie, A, Skogstad, M, Johnsen, TS, Engdahl, B & Tambs, K 2015, 'The prevalence of notched audiograms in a cross-sectional study of 12,055 railway workers', *Ear and hearing*, vol. 36, no. 3, pp. 86–92. https://doi.org/10.1097/AUD.0000000000000129

Mapuranga, M, Maziriri, ET, Letshaba, RK & Chitamba, A 2020, 'Does occupational noise matter among manufacturing (small and medium enterprises) workers? Empirical evidence from Magaba, Mbare, Zimbabwe', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a680. https://doi.org/10.4102/sajcd.v67i2.680

Masia, U & Pienaar, J 2011, 'Unravelling safety compliance in the mining industry: Examining the role of work stress, job insecurity, satisfaction and commitment as antecedents', *South African Journal of Industrial Psychology*, vol. 37, no. 1, a937. https://doi.org/10.4102/sajip.v37i1.937

Mbazima, N 2020, 'Reviving a declining mining industry', *Viewpoints*, viewed 10 March 2021, <https://www.africaportal.org/publications/reviving-declining-mining-industry/>

Minerals Council South Africa (MCSA) 2019, *Mining in SA*, viewed 10 March 2020, <https://www.mineralscouncil.org.za/sa-mining>

Minerals Council South Africa (MCSA) 2020, *Tuberculosis in the South African mining industry: Fact sheet*, viewed 02 February 2021, <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjy5IWYp6_uAhV5ahUIHQtNDksQFjAAegQIARAC&url=https%3A%2F%2Fwww.mineralscouncil.org.za%2Findustry-news%2Fpublications%2Ffact-sheets%2Fsend%2F3-fact-sheets%2F749-tuberculosis-in-south-africa&usg=AOvVaw3pBN1kh6TBoA6SQWbtZKwC>

Moalusi, L & Malesa, G 2019, *Policy and regulatory framework for South Africa's Mining Industry – looking ahead*, viewed 10 March 2020, <https://www.engineeringnews.co.za/article/policy-and-regulatory-framework-for-south-africas-mining-industry---looking-ahead-2019-02-07/rep_id:4136>

Moroe, NF 2018, *Occupational noise-induced hearing loss in South African large-scale mines: From policy formulation to implementation and monitoring*, viewed 10 March 2020, <https://hdl.handle.net/10539/27177>

Moroe, NF 2020, 'Occupational noise-induced hearing loss in South African large-scale mines: Exploring hearing conservation programmes as complex interventions embedded in a realist approach', *International Journal of Occupational Safety and Ergonomics: JOSE*, vol. 26, no. 4, pp. 753–761. https://doi.org/10.1080/10803548.2018.1498183

Moroe, NF & Khoza-Shangase, K 2018, 'Management of occupational noise induced hearing loss in the mining sector in South Africa: Where are the audiologists?', *Journal of Occupational Health*, vol. 60, no. 5, pp. 376–382. https://doi.org/10.1539/joh.2018-0020-OA

Moroe, NF & Khoza-Shangase, K 2020, 'Recent advances in hearing conservation programmes: A systematic review', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a675. https://doi.org/10.4102/sajcd.v67i2.675

Moroe, NF, Khoza-Shangase, K, Madahana, M & Nyandoro, O 2020, 'Feedback-based noise management matrix in action', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a678. https://doi.org/10.4102/sajcd.v67i2.678

Nelson, DI, Nelson, RY, Concha-Barrientos, M & Fingerhut, M 2005, 'The global burden of occupational noise-induced hearing loss', *American Journal of Industrial Medicine*, vol. 48, no. 6, pp. 446–458. https://doi.org/10.1002/ajim.20223

Ntlhakana, L, Nelson, G & Khoza-Shangase, K 2020, 'Estimating miners at risk for occupational noise-induced hearing loss: A review of data from a South African platinum mine', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a677. https://doi.org/10.4102/sajcd.v67i2.677

Ntlhakana, L, Nelson, G, Khoza-Shangase, K & Dorkin, E 2021, 'Occupational hearing loss for platinum miners in South Africa: A case study of data sharing practices and ethical challenges in the mining industry', *International Journal of Environmental Research and Public Health*, vol. 19, no. 1, a1. https://doi.org/10.3390/ijerph19010001

Nupen, L 2020, *Mining in South Africa: Industry challenges in 2020*, viewed 04 January 2021, <https://www.miningreview.com/gold/mining-in-south-africa-industry-challenges-in-2020/>

Oberholzer, C 2010, *South Africa has critical shortage of mining skills*, viewed 10 March 2020, <www.solidaritysa.co.za/Home/wmprint.php?ArtID=2377>

Pillay, M 2020, 'Chemicals, noise and occupational hearing health in South Africa: A mapping study', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a693. https://doi.org/10.4102/sajcd.v67i2.693

Pillay, M & Manning, WG 2020, 'A critical analysis of the current South African occupational health law and hearing loss', *South African Journal of Communication Disorders*, vol. 67, no. 2, a694. https://doi.org/10.4102/sajcd.v67i2.694

Pillay, M, Tiwari, R, Kathard, H & Chikte, U 2020, 'Sustainable workforce: South African audiologists and speech therapists', *Human Resources for Health*, vol. 18, no. 1, pp. 1–13. https://doi.org/10.1186/s12960-020-00488-6

Plecher, H 2020, *Unemployment rate in South Africa 2020*, Statista, viewed 10 January 2021, <https://www.statista.com/statistics/370516/unemployment-rate-in-south-africa/#statisticContainer>

Powell, D & Steytler, N 2010, 'The impact of the global financial crisis on decentralized government in South Africa', *L'Europe en Formation*, vol. 358, no. 4, pp. 149–172. https://doi.org/10.3917/eufor.358.0149

Rabinowitz, PM 2012, 'The public health significance of noise-induced hearing loss', in CG Le Prell, D Henderson, RR Fay & A Popper (eds.), *Noise-induced hearing loss: Scientific advances*, Springer, New York, pp. 13–25.

Ravinder, R & Malindi, M 2014, 'Global financial crises and its impact on the South African economy: A further update', *Journal of Economics*, vol. 5, no. 1, pp. 17–25. https://doi.org/10.1080/09765239.2014.11884980

Reddy, M & Swanepoel, B 2006, ‘Cutting the cost of HIV’, *Harvard Business Review*, vol. 84, no. 9, pp. 21–22. https://hbr.org/2006/09/cutting-the-cost-of-hiv

Reuters 2013, ‘How much is a living wage for miners?’, *Fin24*, viewed 17 April 2018, <https://www.news24.com/Fin24/how-much-is-a-living-wage-for-miners-20130711>

Reuters 2021, *UPDATE 1-South Africa’s unemployment rate reaches new record high in first quarter*, viewed 10 March 2020, <https://www.reuters.com/article/safrica-economy-unemployment-idUSL2N2NJ0NV>

Seixas, NS, Neitzel, R, Stover, B, Sheppard, L, Daniell, B, Edelson, J & Meischke, H 2011, ‘A multi-component intervention to promote hearing protector use among construction workers’, *International Journal of Audiology*, vol. 50, no. Suppl. 1, pp. 46–56. https://doi.org/10.3109/14992027.2010.525754

Smit, AC & Mji, A 2012, ‘Assessment of numeracy levels of mine workers in South African chrome mine’, *Numeracy*, vol. 5, no. 2, a4. https://doi.org/10.5038/1936-4660.5.2.4

Simons, HJ 1960, ‘Death in South African mines’, *Africa South*, vol. 5, no. 4, pp. 41–55. http://www.sahistory.org.za/sites/default/files/DC/asjul61.8/asjul61.8.pdf

Sonnenberg, P, Glynn, JR, Fielding, K, Murray, J, Godfrey-Faussett, P & Shearer, S 2005, ‘How soon after infection with HIV does the risk of tuberculosis start to increase? A retrospective cohort study in South African gold miners’, *Journal of Infectious Diseases*, vol. 191, no. 2, pp. 150–158. https://doi.org/10.1086/426827

South African Mine Health and Safety Council (MHSC) 2016, *Vision, mission, values*, viewed 10 March 2020, <http://www.mhsc.org.za/>

Statistics South Africa (StatsSA) 2017, *Mining: A brief history*, viewed 10 March 2020, <www.statssa.gov.za/?p=9720>

Stuckler, D, Basu, S, McKee, M & Lurie, M 2011, ‘Mining and risk of tuberculosis in sub-Saharan Africa’, *American Journal of Public Health*, vol. 101, no. 3, pp. 524–530. https://doi.org/10.2105/AJPH.2009.175646

Stuckler, D, Steele, S, Lurie, M & Basu, S 2013, ‘“Dying for gold”: The effects of mineral mining on HIV, tuberculosis, silicosis and occupational diseases in southern Africa’, *International Journal of Health Services: Planning, Administration, Evaluation*, vol. 43, no. 4, pp. 639–649. https://doi.org/10.2190/HS.43.4.c

Supplementary Budget Review 2020, *The COVID-19 shock and the revised economic outlook*, viewed 05 January 2021, <http://www.treasury.gov.za/documents/National%20Budget/2020S/review/Chapter%203.pdf>

Thasi, M & Van der Walt, F 2020, ‘Work stress of employees affected by skills shortages in the South African mining industry’, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 120, no. 3, pp. 243–250. https://doi.org/10.17159/2411-9717/666/2020

Twala, C n.d., ‘The Marikana massacre: A historical overview of the labour unrest in the mining sector in South Africa’, *Southern African Peace and Security Studies*, vol. 1, no. 2, pp. 61–67.

Valente, M, Hosford-Dunn, H & Roeser, RJ (eds.) 2008, *Audiology: treatment*, Thieme, New York.

Van Zyl, G 2019, ‘Ivo Vegter: Here’s why mining still matters if SA is to thrive’, *BizNews*, viewed 18 March 2020, <https://www.biznews.com/thought-leaders/2019/03/18/ivo-vegter-why-mining-matters-sa>

World Health Organization (WHO) 2020, *Global tuberculosis report 2020*, viewed 05 March 2021, <https://www.who.int/publications/i/item/9789240013131>

Wilford, A, Phakathi, S, Haskins, L, Jama, NA, Mntambo, N & Horwood, C 2018, ‘Exploring the care provided to mothers and children by community health workers in South Africa: Missed opportunities to provide comprehensive care’, *BMC Public Health*, vol. 18, no. 1, pp. 1–10. https://doi.org/10.1186/s12889-018-5056-y

Wilson, F & South African Council of Churches 1972, *Migrant labour: Report to the South African Council of Churches*, South African Council of Churches and SPRO-CAS, viewed 05 March 2021, <https://www.amazon.com/Migrant-labour-African-Council-Churches/dp/B0006CBKOC>

Yerramilli, P 2015, *South Africa's quadruple burden of disease*, viewed n.d., <https://www.openhealthnews.com/story/2015-03-28/south-africa%E2%80%99s-quadruple-burden-disease>

Zungu, LI 2012, 'Occupational health and safety challenges reported by women in selected South African gold and platinum mines', *Occupational Health Southern Africa*, vol. 18, no. 5, pp. 6–13.

Chapter 3

Agrawal, Y, Platz, EA & Niparko, JK 2009, 'Risk factors for hearing loss in US adults: Data from the National Health and Nutrition Examination Survey, 1999 to 2002', *Otology & Neurotology*, vol. 30, no. 2, pp. 139–145. https://doi.org/10.1097/MAO.0b013e318192483c

Amiri, F, Zamanian, Z, Mani, A & Hasanzadeh, J 2015, 'Effects of combined exposure to noise, heat and lighting on cognitive performance', *Iran Occupational Health*, vol. 12, no. 5, pp. 10–20. http://ioh.iums.ac.ir/article-1-1325-en.html

Amjad-Sardrudi, H, Dormohammadi, A, Golmohammadi, R & Poorolajal, J 2012, 'Effect of noise exposure on occupational injuries: A cross-sectional study', *Journal of Research in Health Sciences*, vol. 12, no. 2, pp. 101–104. http://jrhs.umsha.ac.ir/index.php/JRHS/article/view/750/html

Arslan, E, Orzan, E & Santarelli, R 1999, 'Global problem of drug-induced hearing loss', *Annals of the New York Academy of Sciences*, vol. 884, no. 1, pp. 1–14. https://doi.org/10.1111/j.1749-6632.1999.tb00277.x

Assuiti, LF, Lanzoni, GM, Dos Santos, FC, Erdmann, AL & Meirelles, BH 2013, 'Hearing loss in people with HIV/AIDS and associated factors: An integrative review', *Brazilian Journal of Otorhinolaryngology*, vol. 79, no. 2, pp. 248–255. https://doi.org/10.5935/1808-8694.20130042

Attarchi, M, Dehghan, F, Safakhah, F, Nojomi, M & Mohammadi, S 2011, 'Effect of exposure to occupational noise and shift working on blood pressure in rubber manufacturing company workers', *Industrial Health*, vol. 50, no. 3, pp. 205–213. https://doi.org/10.2486/indhealth.ms1321

Barone, JA, Peters, JM, Garabrant, DH, Bernstein, L & Krebsbach, R 1987, 'Smoking as a risk factor in noise-induced hearing loss', *Journal of Occupational Medicine: Official Publication of the Industrial Medical Association*, vol. 29, no. 9, pp. 741–745.

Basner, M, Babisch, W, Davis, A, Brink, M, Clark, C, Janssen, S & Stansfeld, S 2014, 'Auditory and non-auditory effects of noise on health', *Lancet*, vol. 383, no. 9925, pp. 1325–1332. https://doi.org/10.1016/S0140-6736(13)61613-X

Bhattacharya, SK, Tripathi, SR & Kashyap, SK 1989, 'The combined effects of noise and illumination on the performance efficiency of visual search and neuromotor task components', *Journal of Human Ergology*, vol. 18, no. 1, pp. 41–51.

Bhattacharya, SK, Tripathi, SR & Kashyap, SK 1997, 'Interaction of illumination with noise on neuropsychological performance capability', *Industrial Health*, vol. 35, no. 1, pp. 48–54. https://doi.org/10.2486/indhealth.35.48

Bleecker, ML, Ford, DP, Lindgren, KN, Scheetz, K & Tiburzi, MJ 2003, 'Association of chronic and current measures of lead exposure with different components of brainstem auditory evoked potentials', *Neurotoxicology*, vol. 24, no. 4–5, pp. 625–631. https://doi.org/10.1016/s0161-813x(03)00045-7

Bombard, F, Campo, P & Lataye, R 2005, 'Combined effects of noise and gentamicin on hearing in the guinea pig', *Noise and Health*, vol. 7, no. 28, pp. 29–39. https://doi.org/10.4103/1463-1741.31631

Bowens, A 2018a, *Evidence updates on risk factors for occupational noise-induced hearing loss (ONIHL) update 3: Genetic factors*, viewed 10 March 2020, <https://www.acc.co.nz/assets/research/63e6836c44/ONIHL-evidence-genetics.pdf>

Bowens, A 2018b, *Evidence updates on risk factors for occupational noise-induced hearing loss (ONIHL) update 1: Exposure to solvents with or without noise*, viewed 10 March 2020, <https://www.acc.co.nz/assets/research/23160770fb/ONIHL-evidence-solvents.pdf>

Bunch, CC & Raiford, TS 1931, ‘Race and sex variations in auditory acuity’, *Archives of Otolaryngology*, vol. 13, no. 3, pp. 423–434. https://doi.org/10.1001/archotol.1931.04230020109006

Burström, L, Järvholm, B, Nilsson, T & Wahlström, J 2010, ‘White fingers, cold environment, and vibration-exposure among Swedish construction workers’, *Scandinavian Journal of Work, Environment & Health*, vol. 36, no. 3, pp. 509–513. https://doi.org/10.5271/sjweh.3072

Campo, P, Lataye, R, Cossec, B & Placidi, V 1997, ‘Toluene-induced hearing loss: A mid-frequency location of the cochlear lesions’, *Neurotoxicology and Teratology*, vol. 19, no. 2, pp. 129–140. https://doi.org/10.1016/s0892-0362(96)00214-0

Campo, P, Morata, TC & Hong, O 2013, ‘Chemical exposure and hearing loss’, *Disease-a-Month*, vol. 59, no. 4, pp. 119–138. https://dx.doi.org/10.1016%2Fj.disamonth.2013.01.003

Chang, SJ, Shih, TS, Chou, TC, Chen, CJ, Chang, HY & Sung, FC 2003, ‘Hearing loss in workers exposed to carbon disulfide and noise’, *Environmental Health Perspectives*, vol. 111, no. 13, pp. 1620–1624. https://doi.org/10.1289/ehp.6289

Chang, SJ, Chen, CJ, Lien, CH & Sung, FC 2006, ‘Hearing loss in workers exposed to toluene and noise’, *Environmental Health Perspectives*, vol. 114, no. 8, pp. 1283–1286. https://doi.org/10.1289/ehp.8959

Chao, PC, Juang, YJ, Chen, CJ, Dai, YT, Yeh, CY & Hu, CY 2013, ‘Combined effects of noise, vibration, and low temperature on the physiological parameters of labor employees’, *The Kaohsiung Journal of Medical Sciences*, vol. 29, no. 10, pp. 560–567. https://doi.org/10.1016/j.kjms.2013.03.004

Chen, CJ, Dai, YT, Sun, YM, Lin, YC & Juang, YJ 2007, ‘Evaluation of auditory fatigue in combined noise, heat and workload exposure’, *Industrial Health*, vol. 45, no. 4, pp. 527–534. https://doi.org/10.2486/indhealth.45.527

Chen, GD & Fechter, LD 1999, ‘Potentiation of octave-band noise induced auditory impairment by carbon monoxide’, *Hearing Research*, vol. 132, no. 1–2, pp. 149–159. https://doi.org/10.1016/s0378-5955(99)00044-1

Chen, GD, McWilliams, ML & Fechter, LD 1999, ‘Intermittent noise-induced hearing loss and the influence of carbon monoxide’, *Hearing Research*, vol. 138, no. 1–2, pp. 181–191. https://doi.org/10.1016/s0378-5955(99)00157-4

Chen, KH, Su, SB & Chen, KT 2020, ‘An overview of occupational noise-induced hearing loss among workers: Epidemiology, pathogenesis, and preventive measures’, *Environmental Health and Preventive Medicine*, vol. 25, no. 1, pp. 1–10. https://doi.org/10.1186/s12199-020-00906-0

Choi, YH, Hu, H, Mukherjee, B, Miller, J & Park, SK 2012, ‘Environmental cadmium and lead exposures and hearing loss in US adults: The National Health and Nutrition Examination Survey, 1999 to 2004’, *Environmental Health Perspectives*, vol. 120, no. 11, pp. 1544–1550. https://doi.org/10.1289/ehp.1104863

Chou, YF, Lai, JS & Kuo, HW 2009, ‘Effects of shift work on noise-induced hearing loss’, *Noise and Health*, vol. 11, no. 45, p. 185. https://doi.org/10.4103/1463-1741.56210

Collins, PW 1988, ‘Synergistic interactions of gentamicin and pure tones causing cochlear hair cell loss in pigmented guinea pigs’, *Hearing Research*, vol. 36, no. 2–3, pp. 249–259. https://doi.org/10.1016/0378-5955(88)90066-4

Collins, PW & Twine, JM 1985, ‘The ototoxic effects of different doses of gentamicin on the cochlea of pigmented guinea pigs’, *British Journal of Audiology*, vol. 19, no. 4, pp. 257–264. https://doi.org/10.3109/03005368509078981

Concha-Barrientos, M, Campbell-Lendrum, D & Steenland, K 2004, *Occupational noise: Assessing the burden of disease from work-related hearing impairment at national and local levels*, Environmental Burden of Disease Series, No. 9, viewed 11 January 2021, <https://apps.who.int/iris/handle/10665/43001>

Crofton, KM, Lassiter, TL & Rebert, CS 1994, ‘Solvent-induced ototoxicity in rats: An atypical selective mid-frequency hearing deficit’, *Hearing Research*, vol. 80, no. 1, pp. 25–30. https://doi.org/10.1016/0378-5955(94)90005-1

Crofton, KM & Zhao, X 1993, ‘Mid-frequency hearing loss in rats following inhalation exposure to trichloroethylene: Evidence from reflex modification audiometry’, *Neurotoxicology and Teratology*, vol. 15, no. 6, pp. 413–423. https://doi.org/10.1016/0892-0362(93)90059-w

Cruickshanks, KJ, Klein, R, Klein, BE, Wiley, TL, Nondahl, DM & Tweed, TS 1998, ‘Cigarette smoking and hearing loss: The epidemiology of hearing loss study’, *JAMA*, vol. 279, no. 21, pp. 1715–1719. https://doi.org/10.1001/jama.279.21.1715

Cunningham, DR & Norris, ML 1982, ‘Eye color and noise-induced hearing loss: A population study’, *Ear and Hearing*, vol. 3, no. 4, pp. 211–214. https://doi.org/10.1097/00003446-198207000-00005

Daniel, E 2007, ‘Noise and hearing loss: A review’, *The Journal of School Health*, vol. 77, no. 5, pp. 225–231. https://doi.org/10.1111/j.1746-1561.2007.00197.x

De Jong, MA, Adelman, C, Rubin, M & Sohmer, H 2012, ‘Combined effects of salicylic acid and furosemide and noise on hearing’, *Journal of Occupational Medicine and Toxicology*, vol. 7, no. 1, pp. 1–6. https://doi.org/10.1186/1745-6673-7-1

De Koker, E, Clark, A, Franz, RM & Mackay, JG 2003, ‘Feasibility of using oto-acoustic emission methods for screening early hearing impairment in South African mineworkers’, *SIMRAC Project Health*, vol. 802, pp. 1–8.

Discalzi, G, Fabbro, D, Meliga, F, Mocellini, A & Capellaro, F 1993, ‘Effects of occupational exposure to mercury and lead on brainstem auditory evoked potentials’, *International Journal of Psychophysiology*, vol. 14, no. 1, pp. 21–25. https://doi.org/10.1016/0167-8760(93)90080-9

Dobie, RA 2001, *Medical-legal evaluation of hearing loss*, Cengage Learning, Boston.

Dreisbach, LE, Kramer, SJ, Cobos, S & Cowart, K 2007, ‘Racial and gender effects on pure-tone thresholds and distortion-product otoacoustic emissions (DPOAEs) in normal-hearing young adults’, *International Journal of Audiology*, vol. 46, no. 8, pp. 419–426. https://psycnet.apa.org/doi/10.1080/14992020701355074

Dudarewicz, A, Toppila, E, Pawlaczyk-Łuszczyńska, M & Sliwinska-Kowalska, M 2010, ‘The influence of selected risk factors on the hearing threshold level of noise exposed employees’, *Archives of Acoustics*, vol. 35, no. 3, pp. 371–382. http://dx.doi.org/10.2478/v10168-010-0031-3

Ecob, R, Sutton, G, Rudnicka, A, Smith, P, Power, C, Strachan, D & Davis, A 2008, ‘Is the relation of social class to change in hearing threshold levels from childhood to middle age explained by noise, smoking, and drinking behaviour?’, *International Journal of Audiology*, vol. 47, no. 3, pp. 100–108. https://doi.org/10.1080/14992020701647942

Fabry, DA, Davila, EP, Arheart, KL, Serdar, B, Dietz, NA, Bandiera, FC & Lee DJ 2010, ‘Second-hand smoke exposure and the risk of hearing loss’, *Tobacco Control*, vol. 20, no. 1, pp. 82–85. https://doi.org/10.1136/tc.2010.035832

Farahat, TM, Abdel-Rasoul, GM, El-Assy, AR, Kandil, SH & Kabil, MK 1997, ‘Hearing thresholds of workers in a printing facility’, *Environmental Research*, vol. 73, no. 1–2, pp. 189–192. https://doi.org/10.1006/enrs.1997.3700

Farhadian, M, Aliabadi, M & Darvishi, E 2015, ‘Empirical estimation of the grades of hearing impairment among industrial workers based on new artificial neural networks and classical regression methods’, *Indian Journal of Occupational and Environmental Medicine*, vol. 19, no. 2, pp. 84–9. https://doi.org/10.4103/0019-5278.165337

Fechter, LD 1989, ‘A mechanistic basis for interactions between noise and chemical exposure’, *Archives of Complex Environmental Studies*, vol. 1, no. 1, pp. 23–28.

Fechter, LD, Chen, GD & Rao, D 2002, ‘Chemical asphyxiants and noise’, *Noise & Health*, vol. 4, no. 14, pp. 49–61, viewed 15 March 2020, <https://www.noiseandhealth.org/text.asp?2002/4/14/49/31809>

Fechter, LD, Clerici, WJ, Yao, L & Hoeffding, V 1992, ‘Rapid disruption of cochlear function and structure by trimethyltin in the guinea pig’, *Hearing Research*, vol. 58, no. 2, pp. 166–74. https://doi.org/10.1016/0378-5955(92)90125-7

Fechter, LD & Liu, Y 1997, ‘Auditory toxicology’, in HE Lowndes & KR Rheul (eds.), *Comprehensive toxicology, Vol. 11, chapter 14 nervous system and behavioral toxicology*, Pergamon Press-Elsevier Science, New York, pp. 265–280.

Fechter, LD, Liu, Y, Herr, DW & Crofton, KM 1998, ‘Trichloroethylene ototoxicity: Evidence for a cochlear origin’, *Toxicological Sciences*, vol. 42, no. 1, pp. 28–35. https://doi.org/10.1006/toxs.1997.2413

Fechter, LD, Young, JS & Carlisle, L 1988, ‘Potentiation of noise induced threshold shifts and hair cell loss by carbon monoxide’, *Hearing Research*, vol. 34, no. 1, pp. 39–47. https://doi.org/10.1016/0378-5955(88)90049-4

Ferrite, S & Santana, V 2005, ‘Joint effects of smoking, noise exposure and age on hearing loss’, *Occupational Medicine*, vol. 55, no. 1, pp. 48–53. https://doi.org/10.1093/occmed/kqi002

Ferrite, S, Santana, VS & Marshall, SW 2013, ‘Interaction between noise and cigarette smoking for the outcome of hearing loss among women: A population-based study’, *American Journal of Industrial Medicine*, vol. 56, no. 10, pp. 1213–1220. https://doi.org/10.1002/ajim.22142

Flamme, GA, Deiters, K & Needham, T 2011, ‘Distributions of pure-tone hearing threshold levels among adolescents and adults in the United States by gender, ethnicity, and age: Results from the US National Health and Nutrition Examination Survey’, *International Journal of Audiology*, vol. 50, no. suppl. 1, pp. 11–20. https://doi.org/10.3109/14992027.2010.540582

Forst, LS, Freels, S & Persky, V 1997, ‘Occupational lead exposure and hearing loss’, *Journal of Occupational and Environmental Medicine*, vol. 39, no. 7, pp. 658–660. https://doi.org/10.1097/00043764-199707000-00011

Fransen, E, Topsakal, V, Hendrickx, JJ, Van Laer, L, Huyghe, JR, Van Eyken, E et al. 2008, ‘Occupational noise, smoking, and a high body mass index are risk factors for age-related hearing impairment and moderate alcohol consumption is protective: A European population-based multicenter study’, *Journal of the Association for Research in Otolaryngology*, vol. 9, no. 3, pp. 264–276. https://doi.org/10.1007/s10162-008-0123-1

Fuente, A & McPherson, B 2007, ‘Central auditory damage induced by solvent exposure’, *International Journal of Occupational Safety and Ergonomics* 13(4), 391–397. https://doi.org/10.1080/10803548.2007.11105096

Fuente, A, Slade, MD, Taylor, T, Morata, TC, Keith, RW, Sparer, J & Rabinowitz PM 2009, ‘Peripheral and central auditory dysfunction induced by occupational exposure to organic solvents’, *Journal of Occupational and Environmental Medicine*, vol. 51, no. 10, pp. 1202–1211. https://doi.org/10.1097/JOM.0b013e3181bae17c

Fuortes, LJ, Tang, S, Pomrehn, P & Anderson, C 1995, ‘Prospective evaluation of associations between hearing sensitivity and selected cardiovascular risk factors’, *American Journal of Industrial Medicine*, vol. 28, no. 2, pp. 275–280. https://doi.org/10.1002/ajim.4700280211

Gannon, RP, Tso, SS & Chung, DY 1979, ‘Interaction of kanamycin and noise exposure’, *The Journal of Laryngology & Otology*, vol. 93, no. 4, pp. 341–347. https://doi.org/10.1017/s0022215100087119

Guimaraes, P, Zhu, X, Cannon, T, Kim, S & Frisina, RD 2004, ‘Sex differences in distortion product oto-acoustic emissions as a function of age in CBA mice’, *Hearing Research*, vol. 192, no. 1–2, pp. 83–89. https://doi.org/10.1016/j.heares.2004.01.013

Golbabaei, F, Panjali, Z, Borhani, M, Rahmani, A, Afzali, M & Asghari, M 2014, ‘The effect of environmental factors on job Performance using manual and mental tests’, *Health and Safety at Work*, vol. 4, no. 2, pp. 79–92.

Golmohammadi, R, Amjad Sardrudi, H, Dormohammadi, A & Musavi, S 2012, ‘Study of occupational noise-induced hearing loss in a tractor manufacturing plant’, *Occupational Medicine Quarterly Journal*, vol. 4, no. 3, pp. 28–33, viewed 15 March 2021, <http://tkj.ssu.ac.ir/article-1-206-en.html>

Golmohammadi, R & Darvishi, E 2019, ‘The combined effects of occupational exposure to noise and other risk factors: A systematic review’, *Noise & Health*, vol. 21, no. 101, pp. 125–141. https://doi.org/10.4103%2Fnah.NAH_4_18

Gorai, AK, Siddiqui, TJ, Dey, UK & Singh, G 2007, ‘Combined effect of noise and illumination on worker performance’, *Noise Control Engineering Journal*, vol. 55, no. 4, pp. 417–424. https://doi.org/10.3397/1.2756625

Groenewald, P, Vos, T, Norman, R, Laubscher, R, Van Walbeek, C, Saloojee, U et al. 2007, 'Estimating the burden of disease attributable to smoking in South Africa in 2000', *South African Medical Journal*, vol. 97, no. 8, pp. 674–681.

Hearing Conservation Committee 2003, 'ACOEM evidence-based statement: Noise-induced hearing loss', *Journal of Occupational and Environmental Medicine*, vol. 45, no. 6, pp. 579–581. https://doi.org/10.1097/00043764-200306000-00001

Hederstierna, C & Rosenhall, U 2016, 'Age-related hearing decline in individuals with and without occupational noise exposure', *Noise & Health*, vol. 18, no. 80, p. 21. https://doi.org/10.4103/1463-1741.174375

Heiberg, T & Reid, H 2021, *South Africa's mining industry prepares for $20 million COVID-19 vaccine rollout effort*, viewed 24 November 2021, <https://www.reuters.com/article/uk-health-coronavirus-safrica-vaccines/south-africas-mining-industry-prepares-for-20-million-covid-19-vaccine-rollout-effort-idUSKBN29Y0RN>

Helfer, T 2011, 'Noise-induced hearing injuries, active component, US Armed Forces', *MSMR*, vol. 18, no. 6, pp. 7–10.

Henderson, D, Bielefeld, EC, Harris, KC & Hu, BH 2006, 'The role of oxidative stress in noise-induced hearing loss', *Ear Hear*, vol. 27, no. 1, pp. 1–19. https://doi.org/10.1097/01.aud.0000191942.36672.f3

Henselman, LW, Henderson, D, Shadoan, J, Subramaniam, M, Saunders, S & Ohlin, D 1995, 'Effects of noise exposure, race, and years of service on hearing in US Army soldiers', *Ear and Hearing*, vol. 16, no. 4, pp. 382–391. https://doi.org/10.1097/00003446-199508000-00005

Hong, OS & Kim, MJ 2001, 'Factors associated with hearing loss among workers of the airline industry in Korea', *Orl-head and Neck Nursing: Official Journal of the Society of Otorhinolaryngology and Head-Neck Nurses*, vol. 19, no. 1, pp. 7–13.

Horvath, SM & Bedi, JF 1990, 'Heat, cold, noise, and vibration', *The Medical Clinics of North America*, vol. 74, no. 2, pp. 515–525. https://doi.org/10.1016/s0025-7125(16)30577-6

Hwang, YH, Chiang, HY, Yen-Jean, MC & Wang, JD 2009, 'The association between low levels of lead in blood and occupational noise-induced hearing loss in steel workers', *Science of the Total Environment*, vol. 408, no. 1, pp. 43–49. https://doi.org/10.1016/j.scitotenv.2009.09.016

Hygge, S & Knez, I 2001, 'Effects of noise, heat and indoor lighting on cognitive performance and self-reported affect', *Journal of Environmental Psychology*, vol. 21, no. 3, pp. 291–299. https://doi.org/10.1006/jevp.2001.0222

Iki, M, Kurumatani, N, Satoh, M, Matsuura, F, Arai, T, Ogata, A & Moriyama T 1989, 'Hearing of forest workers with vibration-induced white finger: A five-year follow-up', *International Archives of Occupational and Environmental Health*, vol. 61, no. 7, pp. 437–442. https://doi.org/10.1007/BF00386476

Ishii, EK & Talbott, EO 1998, 'Race/ethnicity differences in the prevalence of noise-induced hearing loss in a group of metal fabricating workers', *Journal of Occupational and Environmental Medicine*, vol. 40, no. 8, pp. 661–666. https://doi.org/10.1097/00043764-199808000-00001

Ishii, EK, Talbott, EO, Findlay, RC, D'Antonio, JA & Kuller, LH 1992, 'Is NIDDM a risk factor for noise-induced hearing loss in an occupationally noise exposed cohort?', *The Science of the Total Environment*, vol. 127, no. 1–2, pp. 155–165. https://doi.org/10.1016/0048-9697(92)90474-7

Jacobsen, P, Hein, HO, Suadicani, P, Parving, A & Gyntelberg, F 1993, 'Mixed solvent exposure and hearing impairment: An epidemiological study of 3284 men. The Copenhagen male study', *Occupational Medicine*, vol. 43, no. 4, pp. 180–184. https://doi.org/10.1093/occmed/43.4.180

Jensen, HI, Markvart, J, Holst, R, Thomsen, TD, Larsen, JW, Eg, DM & Nielsen LS 2016, 'Shift work and quality of sleep: Effect of working in designed dynamic light', *International Archives of Occupational and Environmental Health*, vol. 89, no. 1, pp. 49–61. https://doi.org/10.1007/s00420-015-1051-0

Johnson, AC 1993, 'The ototoxic effect of toluene and the influence of noise, acetyl salicylic acid, or genotype: A study in rats and mice', *Scandinavian Audiology. Supplementum*, vol. 39, pp. 1–40.

Johnson, AC, Juntunen, L, Nylén, P, Borg, E & Höglund, G 1988, 'Effect of interaction between noise and toluene on auditory function in the rat', *Acta Otolaryngologica*, vol. 105, no. 1–2, pp. 56–63. https://doi.org/10.3109/00016488809119446

Johnson, AC, Nylén, P, Borg, E & Höglund, G 1990, 'Sequence of exposure to noise and toluene can determine loss of auditory sensitivity in the rat', *Acta Oto-Laryngologica*, vol. 109, no. 1–2, pp. 34–40. https://doi.org/10.3109/00016489009107412

Kanji, A & Khoza-Shangase, K 2019, 'Early detection of hearing impairment in high-risk neonates: let's talk about the high-risk registry in the South African context', *South African Journal of Child Health*, vol. 13, no. 2, pp. 53–55. http://dx.doi.org/10.7196/sajch.2019.v13i2.1675

Kerketta, S, Gartia, R & Bagh, S 2012, 'Hearing threshold, loss, noise levels and worker's profiles of an open cast chromite mines in Odisha, India', *The Malaysian Journal of Medical Sciences*, vol. 19, no. 4, pp. 63–71.

Kerr, MJ, Neitzel, R, Hong, O & Sataloff, R 2017, 'Historical review of efforts to reduce noise-induced hearing loss in the United States', *American Journal of Industrial Medicine*, vol. 60, pp. 569–577. https://doi.org/10.1002/ajim.22627

Khoza-Shangase, K 2010, 'Is there a need for ototoxicity monitoring in patients with HIV/AIDS?', *African Journal of Pharmacy and Pharmacology*, vol. 4, no. 9, pp. 574–579. http://www.academicjournals.org/ajpp

Khoza-Shangase, K 2013, 'Ototoxicity in tuberculosis treatment in South Africa: Views from healthcare workers involved in the management of TB', *African Journal of Pharmacy and Pharmacology*, vol. 7, no. 30, pp. 2141–2145.

Khoza-Shangase, K 2017, 'Risk versus benefit: Who assesses this in the management of patients on ototoxic drugs?', *Journal of Pharmacy & Bioallied Sciences*, vol. 9, no. 3, pp. 171–177. https://doi.org/10.4103/jpbs.JPBS_17_17

Khoza-Shangase, K 2020, 'Hearing function of gold miners with and without a history of tuberculosis treatment: A retrospective data review', *Brazilian Journal of Otorhinolaryngology*, vol. 86, no. 3, pp. 294–299. https://doi.org/10.1016/j.bjorl.2018.12.003

Khoza-Shangase, K & Kanji, A (eds.) 2021, *Early detection and intervention in audiology: An African perspective*, Wits University Press, Johannesburg.

Khoza-Shangase, K, Moroe, N & Edwards, A 2020, 'Occupational hearing loss in Africa: An interdisciplinary view of the current status', *South African Journal of Communication Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Khoza-Shangase, K, Mupawose, A & Mlangeni, N 2009, 'Ototoxic effects of tuberculosis treatments: How aware are patients?', *African Journal of Pharmacy and Pharmacology*, vol. 3, no. 8, pp. 391–399.

Kilicdag, EB, Yavuz, H, Agis, T, Tarim, E, Erkan, AN & Kazanci, F 2004, 'Effects of estrogen therapy on hearing in postmenopausal women', *American Journal of Obstetrics and Gynecology*, vol. 190, no. 1, pp. 77–82. https://doi.org/10.1016/j.ajog.2003.06.001

Kim, J, Park, H, Ha, E, Jung, T, Paik, N & Yang, S 2005, 'Combined effects of noise and mixed solvents exposure on the hearing function among workers in the aviation industry', *Industrial Health*, vol. 43, no. 3, pp. 567–573. https://doi.org/10.2486/indhealth.43.567

Kirchner, DB, Evenson, E, Dobie, RA, Rabinowitz, P, Crawford, J, Kopke, R & Warner HT 2012, 'Occupational noise-induced hearing loss: ACOEM task force on occupational hearing loss', *Journal of Occupational and Environmental Medicine*, vol. 54, no. 1, pp. 106–108. https://doi.org/10.1097/JOM.0b013e318242677d

Klopper, M, Biagio–de Jager, L &Vinck, B 2019, 'The correlation between hair and eye colour and contralateral suppression of otoacoustic emissions', *Noise & Health*, vol. 21, no. 101, p. 155.

Konings, A, Van Laer, L & Van Camp, G 2009a, 'Genetic studies on noise-induced hearing loss: A review', *Ear Hear*, vol. 30, no. 2, pp. 151–159. https://doi.org/10.1097/AUD.0b013e3181987080

Konings, A, Van Laer, L, Wiktorek-Smagur, A, Rajkowska, E, Pawelczyk, M, Carlsson, PI, Bondeson, ML, Dudarewicz, A, Vandevelde, A, Fransen, E, Huyghe, J, Borg, E, Sliwinska-Kowalska, M & Van Camp G 2009b, 'Candidate gene association study for noise-induced hearing loss in two independent noise-exposed populations', *Annals of Human Genetics*, vol. 73, no. 2, pp. 215–124. https://doi.org/10.1111/j.1469-1809.2008.00499.x

Lacerda, A, Leroux, T & Gagn, JP 2005, 'The combined effect of noise and carbon monoxide on hearing thresholds of exposed workers', *The Journal of the Acoustical Society of America*, vol. 117, no. 4, pp. 2481–2488. https://doi.org/10.1121/1.4787678

Lataye, R & Campo, P 1997, 'Combined effects of a simultaneous exposure to noise and toluene on hearing function', *Neurotoxicology and Teratology*, vol. 19, no. 5, pp. 373–382. https://doi.org/10.1016/s0892-0362(97)00093-7

Le, TN, Straatman, LV, Lea, J & Westerberg, B 2017, 'Current insights in noise-induced hearing loss: a literature review of the underlying mechanism, pathophysiology, asymmetry, and management options', *Journal of Otolaryngology – Head and Neck Surgery*, vol. 46, no. 41, pp. 1–15. https://doi.org/10.1186/s40463-017-0219-x

Lead Regulations 2001, *Protection against particular hazards*, viewed 12 March 2020, <https://www.ilo.org/dyn/natlex/natlex4.detail?p_isn=61838&p_lang=en>

Lebeko, K, Bosch, J, Noubiap, JJ, Dandara, C & Wonkam, A 2015, 'Genetics of hearing loss in Africans: Use of next generation sequencing is the best way forward', *The Pan African Medical Journal*, vol. 20, a383. https://doi.org/10.11604/pamj.2015.20.383.5230

Leroux, T & Klaeboe, R 2012, 'Combined exposures: An update from the International Commission on Biological Effects of Noise', *Noise and Health*, vol. 14, no. 61, p. 313. https://doi.org/10.4103/1463-1741.104900

Li, H & Steyger, P 2009, 'Synergistic ototoxicity due to noise exposure and aminoglycoside antibiotics', *Noise & Health*, vol. 11, no. 42, pp. 26–32. https://doi.org/10.4103/1463-1741.45310

Li, X, Rong, X, Wang, Z & Lin, A 2020, 'Association between smoking and noise-induced hearing loss: a meta-analysis of observational studies', *International Journal of Environmental Research and Public Health*, vol. 17, no. 4, a1201. https://doi.org/10.3390/ijerph17041201

Lie, A, Skogstad, M, Johannessen, HA, Tynes, T, Mehlum, IS, Nordby, KC, Engdahl, B & Tambs K 2016, 'Occupational noise exposure and hearing: A systematic review', *International Archives of Occupational and Environmental Health*, vol. 89, no. 3, p. 351. https://doi.org/10.1007/s00420-015-1083-5

Liebl, A, Haller, J, Jödicke, B, Baumgartner, H, Schlittmeier, S & Hellbrück, J 2012, 'Combined effects of acoustic and visual distraction on cognitive performance and well-being', *Applied Ergonomics*, vol. 43, no. 2, pp. 424–434. https://doi.org/10.1016/j.apergo.2011.06.017

Lin, CC 2014, 'Effect of noise intensity and illumination intensity on visual performance', *Perceptual and Motor Skills*, vol. 119, no. 2, pp. 441–454. https://doi.org/10.2466/26.24.PMS.119c20z1

Lin, FR 2012, 'Hearing loss in older adults: Who's listening?', *JAMA*, vol. 307, no. 11, pp. 1147–1148. https://doi.org/10.1001/jama.2012.321

Lin, FR, Maas, P, Chien, W, Carey, JP, Ferrucci, L & Thorpe, R 2012, 'Association of skin color, race/ethnicity, and hearing loss among adults in the USA', *Journal of the Association for Research in Otolaryngology*, vol. 13, no. 1, pp. 109–117. https://doi.org/10.1007/s10162-011-0298-8

Liu, YM, Li, XD, Li, YS, Guo, X, Xiao, LW, Xiao, QH, et al. 2008, 'Effect of environmental risk factors in occupational noise exposure to noise-induced hearing loss', *Chinese Journal of Industrial Hygiene and Occupational Diseases*, vol. 26, no. 12, pp. 721–724.

Ljungberg, J, Neely, G & Lundström, R 2004, 'Cognitive performance and subjective experience during combined exposures to whole-body vibration and noise', *International Archives of Occupational and Environmental Health*, vol. 77, no. 3, pp. 217–221. https://doi.org/10.1007/s00420-003-0497-7

Lobato, DCB, De Lacerda, ABM, Gonçalves, CGDO & Coifman, H 2014, 'Hearing effects of the exposure to noise and solvents: A comparative study between genders', *International Archives of Otorhinolaryngology*, vol. 8, no. 02, pp. 136–141. https://doi.org/10.1055/s-0033-1361083

Loss, NIH 2003, 'American College and Environmental Medicine evidence-based statement', *Journal of Occupational and Environmental Medicine*, vol. 45, no. 6, pp. 579–581. https://doi.org/10.1097/00043764-200306000-00001

Mac Crawford, J, Hoppin, JA, Alavanja, MC, Blair, A, Sandler, DP & Kamel, F 2008, ‘Hearing loss among licensed pesticide applicators in the agricultural health study running title: Hearing loss among licensed pesticide applicators’, *Journal of Occupational and Environmental Medicine/American College of Occupational and Environmental Medicine*, vol. 50, no. 7, p. 817. https://doi.org/10.1097/JOM.0b013e31816a8caf

Mangipudy, RVS 2010, ‘The impact of eliminating extraneous sound and light on students’ achievement: An empirical study’, Dissertation Abstracts International Section A: Humanities and Social Sciences, viewed 12 March 2020, <https://digitalcommons.fiu.edu/dissertations/AAI3431300/>

Manning, WG & Pillay, M 2020, ‘A critical analysis of the current South African occupational health law and hearing loss’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a694. https://doi.org/10.4102/sajcd.v67i2.694

Marlenga, B, Berg, RL, Linneman, JG, Wood, DJ, Kirkhorn, SR & Pickett, W 2012, ‘Determinants of early-stage hearing loss among a cohort of young workers with 16-year follow-up’, *Occupational and Environmental Medicine*, vol. 69, no. 7, pp. 479–484. https://doi.org/10.1136/oemed-2011-100464

Masterson, EA, Bushnel, PT, Themann, CL & Morata, TC 2016, ‘Hearing impairment among noise-exposed workers – United States, 2003–2012’, *Morbidity and Mortality Weekly Report*, vol. 65, no. 15, pp. 389–394. https://doi.org/10.15585/mmwr.mm6515a2

Mehrparvar, AH, Mollasadeghi, A, Hashemi, SH, Sakhvidi, MJZ, Mostaghaci, M & Davari, MH 2015, ‘Simultaneous effects of noise exposure and smoking on OAEs’, *Noise & Health*, vol. 17, no. 77, pp. 233–249. https://doi.org/10.4103/1463-1741.160716

Metwally, FM, Aziz, HM, Mahdy-Abdallah, H, ElGelil, KSA & El-Tahlawy, EM 2012, ‘Effect of combined occupational exposure to noise and organic solvents on hearing’, *Toxicology and Industrial Health*, vol. 28, no. 10, pp. 901–907. https://doi.org/10.1177%2F0748233711427051

Minerals Council of South Africa (MCSA) 2019, *Women in mining in South Africa: Fact sheet*, viewed 22 January 2021, <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiP5ISPwMDuAhWQTxUIHS9ZACEQFjABegQIBxAC&url=https%3A%2F%2Fwww.mineralscouncil.org.za%2Findustry-news%2Fpublications%2Ffact-sheets%2Fsend%2F3-fact-sheets%2F738-women-in-mining%23%3A~%3Atext%3DThe%2520number%2520of%2520women%2520working%2Cmining%2520labour%2520force%2520of%2520453%252C543.&usg=AOvVaw0qfTwdNzytg7XIUYBSFt_E>

Miyakita, T, Miura, H & Futatsuka, M 1990, ‘Hand-arm vibration, noise, temperature and static load-an experimental study of peripheral circulation while operating chain-saws’, *The Kurume Medical Journal*, vol. 37, suppl., pp. 73–83. https://doi.org/10.2739/kurumemedj.37.SUPPLEMENT_S73

Mizoue, T, Miyamoto, T & Shimizu, T 2003, ‘Combined effect of smoking and occupational exposure to noise on hearing loss in steel factory workers’, *Occupational and Environmental Medicine*, vol. 60, no. 1, pp. 56–59. https://doi.org/10.1136/oem.60.1.56

Mofateh, M, Karimi, Q, Hosseini, MH & Sharif-Zadeh, GR 2017, ‘Effect of smoking on hearing loss in refractory’s factory male worker with occupational noise exposure in Iran’. *The Journal of the Pakistan Medical Association*, vol. 67, no. 4, pp. 605–608.

Mohammadi, S, Labbafinejad, Y & Attarchi, M 2010b, ‘Combined effects of ototoxic solvents and noise on hearing in automobile plant workers in Iran’, *Archives of Industrial Hygiene and Toxicology*, vol. 61, no. 3, pp. 267–274. https://doi.org/10.2478/10004-1254-61-2010-2013

Mohammadi, S, Mazhari, MM, Mehrparvar, AH & Attarchi, MS 2010a, ‘Effect of simultaneous exposure to occupational noise and cigarette smoke on binaural hearing impairment’, *Noise and Health*, vol. 12, no. 48, pp. 187–190. https://doi.org/10.4103/1463-1741.64975

Morata, TC, Dunn, DE, Kretschmer, LW, LeMasters, GK & Keith, RW 1993, ‘Effects of occupational exposure to organic solvents and noise on hearing’, *Scandinavian Journal of Work, Environment & Health*, vol. 19, no. 4, pp. 245–254. https://doi.org/10.5271/sjweh.1477

Morata, TC, Dunn, DE & Sieber, WK 1994, ‘Occupational exposure to noise and ototoxic organic solvents’, *Archives of Environmental Health: An International Journal*, vol. 49, no. 5, pp. 359–365. https://doi.org/10.1080/00039896.1994.9954988

Morata, TC, Engel, T, Durao, A, Costa, TR, Krieg, EF, Dunn, DE & Lozano MA 1997a, 'Hearing loss from combined exposures among petroleum refinery workers', *Scandinavian Audiology*, vol. 26, no. 3, pp. 141–149. https://doi.org/10.3109/01050399709074987

Morata, TC, Fiorini, AC, Fischer, FM, Colacioppo, S, Wallingford, KM, Krieg, EF, Dunn DE, Gozzoli L, Padrão MA & Cesar CLG 1997b, 'Toluene induced hearing loss among rotogravure printing workers', *Scandinavian Journal of Work, Environment & Health*, vol. 23, no. 4, pp. 289–298. https://doi.org/10.5271/sjweh.222

Moroe, N, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise–induced hearing loss in the mining sector in Africa: A systematic review – 1994 to 2016', *Noise & Vibration Worldwide*, vol. 49, no. 5, pp. 181–190. https://doi.org/10.1177/0957456518781860

Moroe, NF 2020, 'Occupational noise-induced hearing loss in South African large-scale mines: Exploring hearing conservation programmes as complex interventions embedded in a realist approach', *International Journal of Occupational Safety and Ergonomics: JOSE*, vol. 26, no. 4, pp. 753–761. https://doi.org/10.1080/10803548.2018.1498183

Murillo-Cuesta, S, Contreras, J, Zurita, E, Cediel, R, Cantero, M, Varela-Nieto, I & Montoliu L 2010, 'Melanin precursors prevent premature age-related and noise-induced hearing loss in albino mice', *Pigment Cell & Melanoma Research*, vol. 23, no. 1, pp. 72–83. https://doi.org/10.1111/j.1755-148X.2009.00646.x

Nash, SD, Cruickshanks, KJ, Klein, R, Klein, BE, Nieto, FJ, Huang, GH, Pankow JS & Tweed TS 2011, 'The prevalence of hearing impairment and associated risk factors: The Beaver Dam Offspring Study', *Archives of Otolaryngology–Head & Neck Surgery*, vol. 137, no. 5, pp. 432–439. https://doi.org/10.1001/archoto.2011.15

Nassiri, P, Ebrahimi, H, Monazzam, MR, Rahimi, A & Shalkouhi, PJ 2014, 'Passenger noise and whole-body vibration exposure: A comparative field study of commercial buses', *Journal of Low Frequency Noise, Vibration and Active Control*, vol. 33, no. 2, pp. 207–220. https://doi.org/10.1260/0263-0923.33.2.207

National Institute for Occupational Safety and Health (NIOSH) 2018, *Noise and hearing loss prevention: Risk factors*, viewed 12 March 2020, <https://www.cdc.gov/niosh/topics/noise/preventhearingloss/riskfactors.html>

Nelson, DI, Nelson, RY, Concha-Barrientos, M & Fingerhut, M 2005, 'The global burden of occupational noise-induced hearing loss', *American Journal of Industrial Medicine*, vol. 48, no. 6, pp. 446–458. https://doi.org/10.1002/ajim.20223

Niranjan, IG 2015, 'A study of co-exposure to chemicals and noise on hearing in the rubber industry', Doctoral dissertation, Durban University of Technology, viewed 12 March 2020, <https://www.semanticscholar.org/paper/A-study-of-co-exposure-to-chemicals-and-noise-on-in-Niranjan/985cfc480ec5ebb290316ac790ad128a7b7f5623>

Ntlhakana, L, Nelson, G, Khoza-Shangase, K & Maposa, I 2021, 'Predicting standard threshold shifts for occupational hearing loss among miners at a large-scale platinum mine in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 121, no. 8, pp. 397–404. https://doi.org/10.17159/2411-9717/1318/2021

Osewe, PL & Nkrumah, Y 2018, *Managing tuberculosis and occupational health in the mining sector in Southern Africa: Health, nutrition and population discussion paper*, World Bank, Washington, viewed 13 March 2020, <https://openknowledge.worldbank.org/handle/10986/30161>

Ozcaglar, HU, Agirdir, B, Dinc, O, Turhan, M, Kilinçarslan, S & Oner, G 2001, 'Effects of cadmium on the hearing system', *Acta Otolaryngologica*, vol. 121, no. 3, pp. 393–397. https://doi.org/10.1080/000164801300102897

Pelders, J & Nelson, G 2019, 'Contributors to fatigue of mine workers in the South African gold and platinum sector', *Safety and Health at Work*, vol. 10, no. 2, pp. 188–195. https://doi.org/10.1016/j.shaw.2018.12.002

Pettersson, H 2013, ‘Risk of hearing loss from combined exposure to hand-arm vibrations and noise’, Doctoral dissertation, Umeå universitet, viewed 10 March 2020, <https://www.diva-portal.org/smash/get/diva2:589455/FULLTEXT01.pdf>

Phaneuf, R & Hetu, R 1990, ‘An epidemiological perspective of the causes of hearing loss among industrial workers’, *The Journal of Otolaryngology*, vol. 19, no. 1, pp. 31–40.

Pilati, N, Ison, MJ, Barker, M, Mulheran, M, Large, CH, Forsythe, ID, Matthias, J & Hamann, M 2012, ‘Mechanisms contributing to central excitability changes during hearing loss’, *Proceedings of the National Academy of Sciences of the United States of America*, vol. 109, no. 21, pp. 8292–8297. https://doi.org/10.1073/pnas.1116981109

Pillay, M 2020, ‘Chemicals, noise and occupational hearing health in South Africa: A mapping study’, *South African Journal of Communication Disorders*, vol. 67, no. 2, pp. 1–11. https://doi.org/10.4102/sajcd.v67i2.693

Pourzarea, G, Attarchi, M, Valirad, F & Mohammadi, S 2016, ‘The effect of simultaneous exposure to organic solvents and noise on high frequency hearing loss in tire manufacturing company workers’, *Occupational Medicine Quarterly Journal*, vol. 8, no. 2, pp. 72–80.

Prasher, D 2009, ‘Heavy metals and noise exposure: Health effects’, *Noise and Health*, vol. 11, no. 44, p. 141. https://doi.org/10.4103/1463-1741.53358

Pratt, SR, Kuller, L, Talbott, EO, McHugh-Pemu, K, Buhari, AM & Xu, X 2009, ‘Prevalence of hearing loss in black and white elders: Results of the cardiovascular health study’, *Journal of Speech, Language, and Hearing Research*, vol. 52, no. 4, pp. 973–989. https://doi.org/10.1044/1092-4388(2009/08-0026)

Pyykkö, I, Toppila, E, Zou, J & Kentala, E 2007, ‘Individual susceptibility to noise-induced hearing loss’, *Audiological Medicine*, vol. 5, no. 1, pp. 41–53. https://doi.org/10.1080/16513860601175998

Republic of South Africa 1995, *Occupational Health and Safety Act, 1993*, Hazardous Chemical Substance Regulations 1995. GNR 1179 of 25 August 1995, Government Printers, Pretoria, viewed 18 March 2018, <http://www.safetycon.co.za/documents/Hazardous%20Chemical%20Substances%20Regulations.pdf>

Republic of South Africa 2000, *National Road Traffic Act: National Road Traffic Regulations, 2000*, GNR.225 of 17 March 2000, Government Printers, Pretoria.

Republic of South Africa 2001, *Occupational Health and Safety Act, 1993*, Hazardous Biological Agents Regulations 2001, GNR 1390 of 27 December 2001, Government Printing Works, Pretoria.

Republic of South Africa 2014, *Occupational Health and Safety Act, 1993*, Construction Regulations 2014, GNR. 84 of 07 February 2014, Government Printing Works, Pretoria.

Rice, DC & Gilbert, SG 1992, ‘Exposure to methyl mercury from birth to adulthood impairs high-frequency hearing in monkeys’, *Toxicology and Applied Pharmacology*, vol. 115, no. 1, pp. 6–10. https://doi.org/10.1016/0041-008x(92)90361-u

Rosenhall, U 2003, ‘The influence of ageing on noise-induced hearing loss’, *Noise and Health*, vol. 5, no. 20, pp. 47–53. https://www.noiseandhealth.org/text.asp?2003/5/20/47/31689

Rubak, T, Kock, SA, Koefoed-Nielsen, B, Bonde, JP & Kolstad, HA 2006, ‘The risk of noise-induced hearing loss in the Danish workforce’, *Noise and Health*, vol. 8, no. 31, pp. 80–87. https://doi.org/10.4103/1463-1741.33538

Ryan, AF & Bone, RC 1982, ‘Non-simultaneous interaction of exposure to noise and kanamycin intoxication in the chinchilla’, *American Journal of Otolaryngology*, vol. 3, no. 4, pp. 264–272. https://doi.org/10.1016/s0196-0709(82)80065-3

Rybak, LP 1986, ‘Drug ototoxicity’, *Annual Review of Pharmacology and Toxicology*, vol. 26, no. 1, pp. 79–99. https://doi.org/10.1146/annurev.pa.26.040186.000455

Rybak, LP 1992, ‘Hearing: the effects of chemicals’, *Otolaryngology Head & Neck Surgery*, vol. 106, no. 6, pp. 677–685. https://doi.org/10.1177%2F019459989210600611

Sakakibara, H, Kondo, TA, Koike, Y, Miyao, M, Furuta, M, Yamada, SY, Sakurai, N & Ono, Y 1989, ‘Combined effects of vibration and noise on palmar sweating in healthy subjects’, *European*

Journal of Applied Physiology and Occupational Physiology, vol. 59, no. 3, pp. 195–198. https://doi.org/10.1007/BF02386187

Saremi, M, Rohmer, O, Burgmeier, A, Bonnefond, A, Muzet, A & Tassi, P 2008, 'Combined effects of noise and shift work on fatigue as a function of age', *International Journal of Occupational Safety and Ergonomics*, vol. 14, no. 4, pp. 387–394. https://doi.org/10.1080/10803548.2008.11076779

Seixas, NS, Neitzel, R, Stover, B, Sheppard, L, Daniell, B, Edelson, J & Meischke, H 2011, 'A multi-component intervention to promote hearing protector use among construction workers', *International Journal of Audiology*, vol. 50, no. suppl. 1, pp. 46–56. https://doi.org/10.3109/14992027.2010.525754

Schellack, N & Naude, A 2013, 'An overview of pharmacotherapy-induced ototoxicity', *South African Family Practice*, vol. 55, no. 4, pp. 357–365. https://doi.org/10.1080/20786204.2013.10874377

Sharabi, Y, Reshef-Haran, I, Burstein, M & Eldad, A 2002, 'Cigarette smoking and hearing loss: Lessons from the young adult periodic examinations in Israel (YAPEIS) database', *The Israel Medical Association Journal: IMAJ*, vol. 4, no. 12, pp. 1118–1120.

Shlomo, M, Avraham, F, Moshe, H, Mario, S, Jacklin, S & Mordechai, H 2002, 'Effects of occupational exposure to mercury or chlorinated hydrocarbons on the auditory pathway', *Noise and Health*, vol. 4, no. 16, p. 71. https://www.noiseandhealth.org/text.asp?2002/4/16/71/31825

Singh, LP, Bhardwaj, A & Deepak, KK 2010, 'Occupational exposure in small and medium scale industry with specific reference to heat and noise', *Noise and Health*, vol. 12, no. 46, p. 37. https://doi.org/10.4103/1463-1741.59998

Sisto, R, Botti, T, Cerini, L, Di Giovanni, R, Marchetti, E, Lunghi, A, Sacco, F, Sanjust, F, Tirabasso, A & Moleti, A 2017, 'Synergistic effects of noise and hand-arm vibration on distortion product otoacoustic emissions in healthy subjects', *International Journal of Industrial Ergonomics*, vol. 62, pp. 48–54. https://doi.org/10.1016/j.ergon.2016.10.006

Sliwinska-Kowalska, M & Davis, A 2012, 'Noise-induced hearing loss', *Noise & Health*, vol. 14, no. 61, pp. 274–280. https://doi.org/10.4103/1463-1741.104893

Sliwinska-Kowalska, M & Pawelczyk, M 2013, 'Contribution of genetic factors to noise induced hearing loss: A human studies review', *Mutation Research*, vol. 752, no. 1, pp. 61–65. https://doi.org/10.1016/j.mrrev.2012.11.001

Sliwinska-Kowalska, M, Dudarewicz, A, Kotylo, P, Zamyslowska-Szmytke, E, Pawlaczyk-Luszczynska, M & Gajda-Szadkowska, A 2006, 'Individual susceptibility to noise-induced hearing loss: Choosing an optimal method of retrospective classification of workers into noise-susceptible and noise-resistant groups', *International Journal of Occupational Medicine and Environmental Health*, vol. 19, no. 4, pp. 235–245. https://doi.org/10.2478/v10001-006-0029-2

Sliwinska-Kowalska, M, Zamyslowska-Szmytke, E, Szymczak, W, Kotylo, P, Fiszer, M, Wesolowski, W, Pawlaczyk-Luszczynska, M, Bak, M & Gajda-Szadkowska A 2004, 'Effects of coexposure to noise and mixture of organic solvents on hearing in dockyard workers', *Journal of Occupational and Environmental Medicine*, vol. 46, no. 1, pp. 30–38. https://doi.org/10.1097/01.jom.0000105912.29242.5b

Sliwinska-Kowalska, M, Zamyslowska-Szmytke, E, Szymczak, W, Kotylo, P, Fiszer, M, Wesolowski, W & Pawlaczyk-Luszczynska, M 2003, 'Ototoxic effects of occupational exposure to styrene and co-exposure to styrene and noise', *Journal of Occupational and Environmental Medicine*, vol. 45, no. 1, pp. 15–24. https://doi.org/10.1097/00043764-200301000-00008

Sliwinska-Kowalska, M, Zamyslowska-Szmytke, E, Szymczak, W, Kotylo, P, Fiszer, M, Wesolowski, W & & Pawlaczyk-Luszczynska, M 2005, 'Exacerbation of noise induced hearing loss by co-exposure to workplace chemicals', *Environmental Toxicology and Pharmacology*, vol. 19, no. 3, pp. 547–553. https://doi.org/10.1016/j.etap.2004.12.018

Sliwinska-Kowalska, M & Zaborowski, K 2017, 'WHO environmental noise guidelines for the European region: A systematic review on environmental noise and permanent hearing loss and tinnitus', *International Journal of Environmental Research and Public Health*, vol. 14, no. 10, a1139. https://doi.org/10.3390/ijerph14101139

Somma, G, Pietroiusti, A, Magrini, A, Coppeta, L, Ancona, C, Gardi, S, Messina, M & Bergamaschi, A 2008, 'Extended high-frequency audiometry and noise induced hearing loss in cement workers', *American Journal of Industrial Medicine*, vol. 51, no. 6, pp. 452–462. https://doi.org/10.1002/ajim.20580

Southern Africa Labour and Development Research Unit 2018, *National income dynamics Study 2017, Wave 5 dataset*, Version 1.0.0, Department of Planning, Monitoring, and Evaluation Agency, Pretoria.

Starck, J, Toppila, E & Pyykkö, I 1999, 'Smoking as a risk factor in sensory neural hearing loss among workers exposed to occupational noise', *Acta Otolaryngologica*, vol. 119, no. 3, pp. 302–305. https://doi.org/10.1080/00016489950181288

StatsSA 2020, *2020 mid-year population estimates*, viewed 28 February 2021, <http://www.statssa.gov.za/?p=13453>

Strauss, S, Swanepoel, DW, Becker, P, Eloff, Z & Hall, JW, III 2014, 'Noise and age-related hearing loss: a study of 40 123 gold miners in South Africa', *International Journal of Audiology*, vol. 53, no. suppl. 2, pp. 66–75. https://doi.org/10.3109/14992027.2013.865846

Sung, JH, Sim, CS, Lee, CR, Yoo, CI, Lee, H, Kim, Y & Lee, J 2013, 'Relationship of cigarette smoking and hearing loss in workers exposed to occupational noise', *Annals of Occupational and Environmental Medicine*, vol. 25, no. 1, p. 110. https://doi.org/10.1186/2052-4374-25-8

Tan, CT, Hsu, CJ, Lee, SY, Liu, SH & Lin-Shiau, SY 2001, 'Potentiation of noise-induced hearing loss by amikacin in guinea pigs', *Hearing Research*, vol. 161, no. 1–2, pp. 72–80. https://doi.org/10.1016/s0378-5955(01)00359-8

Tao, L, Davis, R, Heyer, N, Yang, Q, Qiu, W, Zhu, L, Li, N, Zhang, H, Zeng, L & Zhao, Y 2013, 'Effect of cigarette smoking on noise-induced hearing loss in workers exposed to occupational noise in China', *Noise and Health*, vol. 15, no. 62, pp. 67–73. https://doi.org/10.4103/1463-1741.107159

Toppila, E, Pyykkö, I & Starck, J 2001, 'Age and noise-induced hearing loss', *Scandinavian Audiology*, vol. 30, no. 4, pp. 236–244. https://doi.org/10.1080/01050390152704751

Toppila, E, Pyykkö, II, Starck, J, Kaksonen, R & Ishizaki, H 2000, 'Individual risk factors in the development of noise-induced hearing loss', *Noise & Health*, vol. 2, no. 8, pp. 59–70.

Turcot, A, Girard, SA, Courteau, M, Baril, J & Larocque, R 2015, 'Noise-induced hearing loss and combined noise and vibration exposure', *Occupational Medicine*, vol. 65, no. 3, pp. 238–244. https://doi.org/10.1093/occmed/kqu214

Uchida, Y, Nakashima, T, Ando, F, Niino, N & Shimokata, H 2005, 'Is there a relevant effect of noise and smoking on hearing? A population-based aging study', *International Journal of Audiology*, vol. 44, no. 2, pp. 86–91. https://doi.org/10.1080/14992020500031256

UNAIDS 2020, *Country factsheets: South Africa, 2019*, viewed 13 March 2020, <https://www.unaids.org/en/regionscountries/countries/southafrica>

Unlu, I, Kesici, GG, Basturk, A, Kos, M & Yılmaz, OH 2014, 'A comparison of the effects of solvent and noise exposure on hearing, together and separately', *Noise and Health*, vol. 16, no. 73, p. 410. https://doi.org/10.4103/1463-1741.144422

US Occupational Safety and Health Administration (OSHA) 2002, *Hearing conservation*, viewed 12 March 2020, <https://www.osha.gov/Publications/osha3074.pdf>

Utembe, W, Faustman, EM, Matatiele, P & Gulumian, M 2015, 'Hazards identified and the need for health risk assessment in the South African mining industry', *Human & Experimental Toxicology*, vol. 34, no. 12, pp. 1212–1221. https://doi.org/10.1177/0960327115600370

Vernon, J, Jeff, B, Meikle, M & Brummett, RE 1978, 'The potentiation of noise-induced hearing loss by neomycin', *Otolaryngology*, vol. 86, no. 1, pp. 123–124. https://doi.org/10.1177/019459987808600129

Vos, T, Flaxman, AD, Naghavi, M, Lozano, R, Michaud, C, Ezzati, M et al. 2012, 'Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: A systematic analysis for the Global Burden of Disease Study 2010', *Lancet*, vol. 380, pp. 2163–2196. https://doi.org/10.1016/S0140-6736(12)61729-2

Watts, KL 2019, 'Ototoxicity: Visualised in concept maps', *Seminars in Hearing*, vol. 40, no. 2, pp. 177–187. https://doi.org/10.1055/s-0039-1684046

Wild, DC, Brewster, MJ & Banerjee, AR 2005, ‘Noise-induced hearing loss is exacerbated by long-term smoking’, *Clinical Otolaryngology*, vol. 30, no. 6, pp. 517–520. https://doi.org/10.1111/j.1749-4486.2005.01105.x

World Health Organization (WHO) 2010, *Burden of disease from environmental noise*, viewed 13 March 2020, <https://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf>

World Health Organization (WHO) 2018, *Country cooperation strategy at a glance*, viewed 13 March 2020, <https://apps.who.int/iris/bitstream/handle/10665/136874/ccsbrief_zaf_en.pdf;jsessionid=E4076B95B82E47064DB7DB3E8F795799?sequence=1>

Wonkam Tingang, E, Noubiap, JJ, Fokouo, JV, Oluwole, OG, Nguefack, S, Chimusa, ER & Wonkam, A 2020, ‘Hearing impairment overview in Africa: The case of Cameroon’, *Genes*, vol. 11, no. 2, a233. https://doi.org/10.3390/genes11020233

Wu, MF, Ison, JR, Wecker, JR & Lapham, LW 1985, ‘Cutaneous and auditory function in rats following methyl mercury poisoning’, *Toxicology and Applied Pharmacology*, vol. 79, no. 3, pp. 377–388. https://doi.org/10.1016/0041-008x(85)90136-x

Wu, TN, Shen, CY, Lai, JS, Goo, CF, Ko, KN, Chi, HY, Chang, PY & Liou, SH 2000, ‘Effects of lead and noise exposures on hearing ability’, *Archives of Environmental Health: An International Journal*, vol. 55, no. 2, pp. 109–114. https://doi.org/10.1080/00039890009603396

Yang, HY, Shie, RH & Chen, PC 2016, ‘Hearing loss in workers exposed to epoxy adhesives and noise: a cross-sectional study’, *BMJ Open*, vol. 6, no. 2, pp. 33–38. https://doi.org/10.1136/bmjopen-2015-010533

Yang, W & Moon, HJ 2018, ‘Combined effects of sound and illuminance on indoor environmental perception’, *Applied Acoustics*, vol. 141, pp. 136–143. https://doi.org/10.1016/j.apacoust.2018.07.008

Yoshioka, M, Uchida, Y, Sugiura, S, Ando, F, Shimokata, H, Nomura, H & Nakashima, T 2010, ‘The impact of arterial sclerosis on hearing with and without occupational noise exposure: A population-based aging study in males’, *Auris Nasus Larynx*, vol. 37, no. 5, pp. 558–564. https://doi.org/10.1016/j.anl.2010.02.006

Yousaf, R, Friedman, TB & Riazuddin, S 2016, ‘Genetic modifiers of hearing loss’, eds. B Vona & T Haaf), *Genetics of deafness*, vol. 20, Karger Publishers, Basel, pp. 73–83.

Young, JS, Upchurch, MB, Kaufman, MJ & Fechter, LD 1987, ‘Carbon monoxide exposure potentiates high-frequency auditory threshold shifts induced by noise’, *Hearing Research*, vol. 26, no. 1, pp. 37–43. https://doi.org/10.1016/0378-5955(87)90034-7

Young, SK, Youn, HC, Oh, JK, Seong, WC & Kyung, YR 2011, ‘The risk rating system for noise-induced hearing loss in Korean manufacturing sites based on the 2009 survey on work environments’, *Safety and Health at Work*, vol. 2, no. 4, pp. 336–347. https://doi.org/10.5491/SHAW.2011.2.4.336

Zamanian, Z, Golmohamadi, R, Abedini, R, Hossinzadeh, K, Soltanzadeh, A & Ghiasvand, R 2013, ‘The effect of smoking and noise-induced hearing loss’, *Saudi Journal of Health Systems Research*, vol. 9, pp. 640–647.

Zenz, C, Dickerson, OB & Horvath, EP 1994, *Occupational medicine*, 3rd edn., Mosby, St. Louis.

Zhang, X, Ni, Y, Liu, Y, Zhang, L, Zhang, M, Fang, X, Yang, Z, Wang, Q, Li, H, Xia, Y & Zhu, Y 2019, ‘Screening of noise-induced hearing loss (NIHL)-associated SNPs and the assessment of its genetic susceptibility’, *Environmental Health*, vol. 18, no. 1, p. 30. https://doi.org/10.1186/s12940-019-0471-9

Zhu, SK, Sakakibara, H & Yamada, SY 1997, ‘Combined effects of hand-arm vibration and noise on temporary threshold shifts of hearing in healthy subjects’, *International Archives of Occupational and Environmental Health*, vol. 69, no. 6, pp. 433–436. https://doi.org/10.1007/s004200050171

Chapter 4

Australian Safety and Compensation Council 2006, *Work-related noise induced hearing loss in Australia*, Commonwealth of Australia, viewed 10 March 2021, <https://www.safeworkaustralia.gov.au/system/files/documents/1702/workrelated_noise_induced_hearing.pdf>

Azizi, MH 2010, 'Occupational noise-induced hearing loss', *The International Journal of Occupational and Environmental Medicine*, vol. 1, no. 3, pp. 116–123.

Booyens, Y 2013, 'Noise induced hearing loss worrying – CoM', *Creamer Media: Mining Weekly [Internet]*, viewed 09 March 2020, <http://www.miningweekly.com/article/noise-induced-hearing-loss-worrying-com-2013-05-20>

Brits, J, Strauss, S, Eloff, Z, Becker, PJ & Swanepoel, DW 2012, 'Hearing profile of gold miners with and without tuberculosis', *Occupational and Environmental Medicine*, vol. 69, no. 4, pp. 243–249. https://doi.org/10.1136/oemed-2011-100106

Chen, KH, Su, SB & Chen, KT 2020, 'An overview of occupational noise-induced hearing loss among workers: Epidemiology, pathogenesis, and preventive measures', *Environmental Health and Preventive Medicine*, vol. 25, no. 1, p. 65. https://doi.org/10.1186/s12199-020-00906-0

COIDA 1993, *Compensation for Occupational Injuries and Diseases Act 130 of 1993,* viewed 10 January 2018, <https://www.gov.za/sites/default/files/gcis_document/201409/act130of1993.pdf>

Concha-Barrientos, M, Campbell-Lendrum, D & Steenland, K 2004, 'Occupational noise: Assessing the burden of disease from work-related hearing impairment at national and local levels', *WHO Environmental Burden of Disease*, vol. 9, pp. 1–41. https://apps.who.int/iris/handle/10665/43001

Coulson, N 2018, 'The role of workplace health and safety representatives and the creeping responsibilisation of occupational health and safety on South African mines', *Resources Policy*, vol. 56, pp. 38–48. https://doi.org/10.1016/j.resourpol.2018.02.007

Cullinan, K 2018, 'R1.4 billion settlement for miners with silicosis, TB', *Health24*, viewed 10 January 2021, <https://www.news24.com/health24/news/public-health/r14-billion-settlement-for-miners-with-silicosis-tb-20180508>

Dekker, JJ, Edwards, AL, Franz, RM, Van Dyk, T & Banyini, A 2011, 'Meeting the milestones: Are South African small-to medium-scale mines up to the task?', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 5, pp. 309–313. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532011001700002&lng=en&nrm=iso

Department of Labour 2001, *Circular instruction no. 171: The determination of permanent disablement resulting from hearing loss caused by exposure to excessive noise and trauma*, Department of Labour, Pretoria, viewed 10 January 2021, <https://www.gov.za/sites/default/files/gcis_document/201409/22296.pdf>

Edwards, AL, Dekker, JJ, Franz, RM, Van Dyk, T & Banyini, A 2011, 'Profiles of noise exposure levels in South African Mining', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 5, pp. 315–322. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532011001700003&lng=en&nrm=iso

Edwards, AL & Kritzinger, D 2012, 'Noise-induced hearing loss milestones: Past and future', *The Journal of The Southern African Institute of Mining and Metallurgy*, vol. 112, pp. 865–869. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532012001000006&lng=en&nrm=iso

European Agency for Safety and Health at Work 2005, *Risk observatory thematic report: Noise in figures*, viewed 10 January 2021, <https://osha.europa.eu/en/publications/report-noise-figures>

Franz, RM & Phillips, JJ 2001, 'Noise and vibration', in R Guild (ed.), *Handbook of occupational health practice in the South African Mining Industry*, The Safety in Mines Research Advisory Committee (SAMRAC), Johannesburg, pp. 195–232.

Girard, SA, Leroux, T, Courteau, M, Picard, M, Turcotte, F & Richer, O 2015, 'Occupational noise exposure and noise-induced hearing loss are associated with work-related injuries leading to admission to hospital', *Injury Prevention*, vol. 21, no. e1, pp. 88–92. https://doi.org/10.1136/injuryprev-2013-040828

Gray, A & Vawda, Y 2016, *Health policy and legislation*, Health Systems Trust, viewed 10 February 2020, <https://www.hst.org.za/publications/South%20African%20Health%20Reviews/1%20Health%20Policy%20and%20Legislation.pdf>

Kanji, A, Khoza-Shangase, K & Ntlhakana, L 2019, 'Noise induced hearing loss: What South African mineworkers know', *International Journal of Occupational Safety and Ergonomics*, vol. 25, no. 2, pp. 305–310. https://doi.org/10.1080/10803548.2017.1412122

Kew, G 2018, 'A review of current practice and a need for new ideas to solve an old problem', in *SASOM conference occupational medicine specialist Protea Hotel by Marriott,* Oliver Tambo International Airport, 22–23 June, Kempton Park, Gauteng.

Khoza-Shangase, K 2020a, 'Hearing Function of gold miners with and without a history of tuberculosis: Treatment: A retrospective data review', *Brazilian Journal of Otorhinolaryngology*, vol. 86, no. 3, pp. 294–299. https://doi.org/10.1016/j.bjorl.2018.12.003

Khoza-Shangase, K 2020b, 'Burden of disease: A scoping review of HIV/AIDS and TB in occupational noise-induced hearing loss', *South African Journal of Communication Disorders*, vol. 67, no. 2, a669. https://doi.org/10.4102/sajcd.v67i2.669

Khoza-Shangase, K 2021, 'Confronting realities to early hearing detection in South Africa', in K Khoza-Shangase & A. Kanji (eds.), *Early detection and intervention in audiology: An African perspective*, Wits University Press, Johannesburg, pp. 6–68.

Khoza-Shangase, K, Moroe, NF & Edwards, A 2020, 'Occupational hearing loss in Africa: An interdisciplinary view of the current status', *South African Journal of Communication Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Kurmis, AP & Apps, SA 2007, 'Occupationally-acquired noise-induced hearing loss: A senseless workplace hazard', *International Journal of Occupational Medicine and Environmental Health*, vol. 20, no. 2, pp. 127–136. https://doi.org/10.2478/v10001-007-0016-2

Le, TN, Straatman, LV, Lea, J & Westerberg, B 2017, 'Current insights in noise-induced hearing loss: A literature review of the underlying mechanism, pathophysiology, asymmetry, and management options', *Journal of Otolaryngology – Head and Neck Surgery*, vol. 46, no. 41, pp. 1–15. https://doi.org/10.1186/s40463-017-0219-x

Leboea, ST 2017, 'The factors influencing SME failure in South Africa', MCom dissertation, University of Cape Town, University of Cape Town, viewed 12 January 2021, <http://hdl.handle.net/11427/25334>

Lehohla, PJ 2017, *Whither a demographic dividend South Africa: The Overton window of political possibilities*, Statistics South Africa, viewed 17 January 2021, <http://www.statssa.gov.za/publications/OP001/OP0012017.pdf>

MacLurg, K, McCaughan, J & McQuillan, P 2004, 'Hearing surveillance chart: A tool for tracking serial audiometry results and predicting future hearing impairment', *Occupational Medicine*, vol. 54, no. 8, pp. 583–584. https://doi.org/10.1093/occmed/kqh100

Morata, TC & Meinke, D 2016, 'Uncovering effective strategies for hearing loss prevention', *Acoustics Australia*, vol. 44, no. 1, pp. 67–75. https://doi.org/10.1007/s40857-016-0044-9

Moroe, N, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise–induced hearing loss in the mining sector in Africa: A systematic review – 1994 to 2016', *Noise & Vibration Worldwide*, vol. 49, no. 5, pp. 181–190. https://doi.org/10.1177/0957456518781860

Moroe, N, Khoza-Shangase, K, Madahana, M & Nyandoro, O 2019, 'A proposed preliminary model for monitoring hearing conservation programmes in the mining sector in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 119, no. 7, pp. 671–679. https://doi.org/10.17159/2411-9717/18/016/2019

Moroe, NF, Khoza-Shangase, K, Madahana, MCI & Nyandoro, OTC 2020, 'Feedback-based noise management matrix in action', *South African Journal of Communication Disorders*, vol. 67, no. 2, a678. https://doi.org/10.4102/sajcd.v67i2.678

Moroe, NF 2018, 'Occupational noise-induced hearing loss in South African large scale mines: From policy formulation to implementation and monitoring', doctoral dissertation, viewed 23 January 2019, <https://hdl.handle.net/10539/27177>

Moroe, NF 2020, 'Occupational noise-induced hearing loss in South African large-scale mines: Exploring hearing conservation programmes as complex interventions embedded in a realist approach', *International Journal of Occupational Safety and Ergonomics*, vol. 26, no. 4, pp. 753–761. https://doi.org/10.1080/10803548.2018.1498183

Moroe, NF & Khoza-Shangase, K 2018, ‘Management of occupational noise-induced hearing loss in the mining sector in South Africa: Where are the audiologists?’, *Journal of Occupational Health*, vol. 60, no. 5, pp. 376–382. https://doi.org/10.1539/joh.2018-0020-OA

Nair, DC 2014, ‘Noise-induced hearing loss’, *InnovAiT*, vol. 7, no. 4, pp. 204–208. https://doi.org/10.1177/1755738013518903

Nandi, SS & Dhatrak, SV 2008, ‘Occupational noise-induced hearing loss in India’, *Indian Journal of Occupational and Environmental Medicine*, vol. 12, no. 2, pp. 53–56. https://doi.org/10.4103/0019-5278.43260

Nelson, DI, Nelson, RY, Concha-Barrientos, M & Fingerhut, M 2005, ‘The global burden of occupational noise-induced hearing loss’, *American Journal of Industrial Medicine*, vol. 48, no. 6, pp. 446–458. https://doi.org/10.1002/ajim.20223

NIOSH 2020, *NIOSH list of hazardous drugs in healthcare settings, 2020*, viewed 10 January 2021, <https://www.cdc.gov/niosh/docket/review/docket233c/pdfs/DRAFT-NIOSH-Hazardous-Drugs-List-2020.pdf>

Nkosi, V, Claassen, N & Voyi, K 2015, ‘Occupational noise-induced hearing loss prevalence and noise abatement techniques in a steel-making plant’, *Occupational Health Southern Africa*, vol. 21, no. 5, pp. 12–19. https://hdl.handle.net/10520/EJC178129

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’, *Occupational Health Southern Africa*, vol. 21, no. 2, pp. 10–15.

Ntlhakana, L, Nelson, G & Khoza-Shangase, K 2020a, ‘Estimating miners at risk for occupational noise-induced hearing loss: a review of data from a South African platinum mine’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a677. https://doi.org/10.4102/sajcd.v67i2.677

Ntlhakana, L, Khoza-Shangase, K & Nelson, G 2020b, ‘Occupational noise-induced hearing loss in platinum miners: what do the data tell us?’, *Occupational Health Southern Africa*, vol. 26, no. 1, pp. 8–14. https://doi.org/10.17159/2411-9717/1318/2021

Oosthuizen, SDW 2006, *Guidelines for hearing conservation programmes*, Provincial Occupational Health Unit, Bloemfontein.

Pelders, J & Nelson, G 2019, ‘Contributors to fatigue of mine workers in the South African gold and platinum sector’, *Safety and Health at Work*, vol. 10, no. 2, pp. 188–195.

Phillips, JI, Heyns, PS & Nelson, G 2007, ‘Rock drills used in South African mines: a comparative study of noise and vibration levels’, *The Annals of Occupational Hygiene*, vol. 51, no. 3, pp. 305–310. https://doi.org/10.1093/annhyg/mel082

Prasher, D 2009, ‘Heavy metals and noise exposure: health effects’, *Noise and Health*, vol. 11, no. 44, p. 141. https://doi.org/10.4103/1463-1741.53358

Pulsar Instrument 2020, *Understanding the 3dB rule*, viewed 10 January 2021, <https://pulsarinstruments.com/news/understanding-3db-rule/>

Ranga, RK, Yadav, SPS, Yadav, A, Yadav, N & Ranga, SB 2014, ‘Prevalence of occupational noise induced hearing loss in industrial workers’, *Indian Journal of Otology*, vol. 20, no. 3, p. 115. https://www.indianjotol.org/text.asp?2014/20/3/115/136848

Safe Work Australia 2010, *Occupational noise-induced hearing loss in Australia*: *Overcoming barriers to effective noise control and hearing loss prevention*, Safe Work Australia, Canberra.

Sam, WY, Anita, AR, Hayati, KS, Haslinda, A & Lim, CS 2017, ‘Prevalence of hearing loss and hearing impairment among small and medium enterprise workers in Selangor, Malaysia’, *Sains Malaysiana*, vol. 46, no. 2, pp. 267–274.

Sliwinska-Kowalska, M 2020, ‘New trends in the prevention of occupational noise-induced hearing loss’, *International Journal of Occupational Medicine and Environmental Health*, vol. 33, no. 6, pp. 841–848. https://doi.org/10.13075/ijomeh.1896.01600

Sliwinska-Kowalska, M & Davis, A 2012, ‘Noise-induced hearing loss’, *Noise and Health*, vol. 14, no. 61, pp. 274–280. https://doi.org/10.4103/1463-1741.104893

South African Mine Health and Safety Council (MHSC) 2014b, ‘Every mine worker returning from work unharmed every day: Striving for zero harm’, *paper presented at the Proceedings of* *the 10th anniversary of the 2003 Occupational Health and Safety milestones*, Woodmead, Johannesburg, 19–20 November.

South African Mine Health and Safety Council (MHSC) 2014a, *2014 MHSC summit: Every mine worker returning from work unharmed every day striving for zero harm*, Mine Health and Safety Council, viewed 19 January 2018, <https://mhsc.org.za/sites/default/files/public/research_documents/2014%20OHS%20Summit%20Milestones.pdf>

South African Mine Health and Safety Council (MHSC) 2015, *Occupational health summit*, Occupational Health Southern Africa, viewed 30 October 2017, <https://www.oldcollab.co.za/resources/working-group-statements/2015>

Strauss, S, Swanepoel, D, Becker, P, Eloff, Z & Hall, JW 2012, 'Prevalence and degree of noise induced hearing loss in South African gold miners', *Occupational Health Southern Africa*, vol. 18, no. 6, p. 5.

Stuckler, D, Basu, S, McKee, M & Lurie, M 2011, 'Mining and risk of tuberculosis in Sub-Saharan Africa', *American Journal of Public Health*, vol. 101, no. 3, pp. 524–530. https://dx.doi.org/10.2105%2FAJPH.2009.175646

Stuckler, D, Steele, S, Lurie, M & Basu, S 2013, '"Dying for gold": The effects of mineral mining on HIV, tuberculosis, silicosis and occupational diseases in southern Africa', *International Journal of Health Services: Planning, Administration, Evaluation*, vol. 43, no. 4, pp. 639–649. https://doi.org/10.2190/HS.43.4.c

Suter, AH 2012, 'Engineering controls for occupational noise exposure: The best way to save hearing', *Sound and Vibrations*, vol. 45, pp. 24–31. http://www.sandv.com/downloads/1201sute.pdf

Tak, S, Davis, RR & Calvert, GM 2009, 'Exposure to hazardous workplace noise and use of hearing protection devices among US workers – NHANES, 1999–2004', *American Journal of Industrial Medicine*, vol. 52, no. 5, pp. 358–371. https://doi.org/10.1002/ajim.20690

Teke, Z 2017, 'Probe into struggles of ex-miners', *Sunday Tribune*, viewed 10 January 2021, <https://web.archive.org/web/20211125140639/https://www.iol.co.za/sunday-tribune/news/probe-into-struggles-of-ex-miners-11515422>

Van Coller, P 2015, 'Noise exposure in an opencast platinum mine in the Limpopo Province during 2006–2010', Master in Public Health in the field of Occupational Hygiene thesis, viewed 10 January 2021, <https://wiredspace.wits.ac.za/items/41720d14-16a6-44c6-9c49-340895663ef8>

World Health Organization (WHO) 2020, *Global tuberculosis report 2020*, viewed 15 January 2021, <https://www.who.int/publications/i/item/9789240013131>

Worldwide Recruitment Solutions 2014, *Media statement,* viewed 26 January 2020, <https://www.engineeringnews.co.za/article/worldwide-recruitment-solutions-2014-02-28>

Yamashita, D, Jiang, H-Y, Le Prell, CG, Schacht, J & Miller, JM 2005, 'Post-exposure treatment attenuates noise-induced hearing loss', *Neuroscience*, vol. 134, no. 2, pp. 633–642. https://doi.org/10.1016/j.neuroscience.2005.04.015

Zhou, J, Shi, Z, Zhou, L, Hu, Y & Zhang, M 2020, 'Occupational noise-induced hearing loss in China: A systematic review and meta-analysis', *BMJ Open*, vol. 10, no. 9, a039576. https://doi.org/10.1136/bmjopen-2020-039576

Chapter 5

American College of Occupational and Environmental Medicine (ACOEM) 2003, 'The ACOEM position statement on noise-induced hearing loss', *Now Hear This*, vol. 5, no. 4, pp. 1–3. https://oem.msu.edu/images/newsletter/NowHearThis/Hv5n4.pdf

Attarchi, MS, Sadeghi, Z, Faezeh, D, Sohrabi, MM & Saber, M 2010, 'Assessment of hearing standard threshold shift based on audiometric findings in steel company workers', *Iranian Red Crescent Medical Journal*, vol. 12, no. 6, pp. 644–649.

Azizi, MH 2010, 'Occupational noise-induced hearing loss', *Academy of Medical Sciences of the IR*, vol. 1, no. 3, pp. 116–123.

Booi, M 2020, 'Learning more from the hearing conservation programme's medical surveillance data', *Occupational Health Southern Africa*, vol. 26, no. 4, a12. https://hdl.handle.net/10520/ejc-ohsa-v26-n4-a12

Bronkhorst, JP & Schutte, DW 2013, 'Reconstruction of percentage loss of hearing', *Occupational Health Southern Africa*, vol. 19, no. 3, pp. 20–24.

Cameron, I & McBain, C 2019, 'Occupational noise induced hearing loss and audiometry', *The State Insurance Regulatory Authority*, viewed 10 January 2021, <https://www.sira.nsw.gov.au/__data/assets/pdf_file/0006/603429/Occupational-Noise-Induced-Hearing-Loss-and-Audiometry-rapid-review.pdf>

Charih, F., Bromwich, M., Mark, A.E., Lefrançois, R & Green, J.R 2020, 'Data-driven audiogram classification for mobile audiometry', *Scientific Reports*, vol. 10, no. 1, p. 3962. https://doi.org/10.1038/s41598-020-60898-3

Chau, JK, Cho, JJW & Fritz, DK 2012, 'Evidence-based practice: Management of adult sensorineural hearing loss', *Otolaryngologic Clinics of North America*, vol. 45, pp. 941–958. https://doi.org/10.1016/j.otc.2012.06.002

Cheesman, M & Steinberg, P 2010, 'Health surveillance for noise-induced hearing loss (NIHL)', *Occupational Medicine*, vol. 60, no. 7, pp. 576–577. https://doi.org/10.1093/occmed/kqq125

Codling, A & Fox, D 2017, 'Current practices in noise health surveillance: An exploratory study on the delivery of noise health surveillance programmes in Britain', *Occupational Health at Work*, vol. 14, no. 2, pp. 31–35.

Cunningham, LL & Tucci, DL 2017, 'Hearing loss in adults', *The New England Journal of Medicine*, vol. 377, no. 25, pp. 2465–2473. https://doi.org/10.1056/NEJMra1616601

Dillon, H, Beach, EF, Seymour, J, Carter, L & Golding, M 2016, 'Development of telscreen: A telephone-based speech-in-noise hearing screening test with a novel masking noise and scoring procedure', *International Journal of Audiology*, vol. 55, no. 8, pp. 463–471. https://doi.org/10.3109/14992027.2016.1172268

Edwards, AL & Kritzinger, D 2012, 'Noise-induced hearing loss milestones: Past and future', *The Journal of The Southern African Institute of Mining and Metallurgy*, vol. 112, pp. 865–869. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532012001000006&lng=en&nrm=iso

Edwards, A, Van Coller, P & Badenhorst, C 2010, *Early identification of noise induced hearing loss: A pilot study on the use of distortion product otoacoustic emissions as an adjunct to screening audiometry in the mining industry*, viewed 12 January 2021, <http://hdl.handle.net/10204/4807>

eMoyo 2020, *Occupational health audiometric testing in South Africa explained (Part 1)*, viewed 11 January 2021, <https://emoyo.net/post-kudu/occupational-health-audiometric-testing-in-south-africa-explained-part-1/>

Fredriksson, S, Hammar, O, Magnusson, L, Kahari, K & Waye, KP 2016, 'Validating self-reporting of hearing-related symptoms against pure-tone audiometry, otoacoustic emission, and speech audiometry', *International Journal of Audiology*, vol. 55, no. 8, pp. 454–462. https://doi.org/10.1080/14992027.2016.1177210

Hain, TC 2007, 'Cranial nerve VIII: Vestibulocochlear system', in CG Goetz (ed.), *Textbook of clinical neurology*, 3rd edn., W.B. Saunders Elsevier, Philadelphia, pp. 199–215.

Hedge, MN 1987, 'Observation and measurement', eds. MN Hedge, *Clinical research in communicative disorders*, College-Hill Press, Boston, pp. 105–106.

Hong, O, Kerr, MJ, Poling, GL & Dhar, S 2013, 'Understanding and preventing noise-induced hearing loss', *Disease-a-Month*, vol. 59, no. 4, pp. 110–118. https://doi.org/10.1016/j.disamonth.2013.01.002

Jerger, J 2013, 'Why the audiogram is upside-down', *International Journal of Audiology*, vol. 52, no. 3, pp. 146–150. https://doi.org/10.3109/14992027.2012.752112

Kew, G 2018, ‘A review of current practice and a need for new ideas to solve an old problem’, *SASOM Conference Occupational Medicine Specialists*, Kempton Park.

Khoza-Shangase, K 2020, ‘Hearing function of gold miners with and without a history of tuberculosis treatment: A retrospective data review’, *Brazilian Journal of Otorhinolaryngology*, vol. 86, no. 3, pp. 294–299. https://doi.org/10.1016/j.bjorl.2018.12.003

Khoza-Shangase, K, Moroe, NF & Edwards, A 2020, ‘Occupational hearing loss in Africa: An interdisciplinary view of the current status’, *South African Journal of Communication Disorders*, vol. 67, no. 2, pp. 1–3. https://dx.doi.org/10.4102%2Fsajcd.v67i2.700

Kirchner, DB, Evenson, E, Dobie, RA, Rabinowitz, P, Crawford, J, Kopke, R & Hudson, TW 2012, ‘Occupational noise-induced hearing loss’, *Journal of Occupational and Environmental Medicine*, vol. 54, no. 1, pp. 106–108. https://doi.org/10.1097/JOM.0b013e318242677d

Le, TN, Straatman, LV, Lea, J & Westerberg, B 2017, ‘Current insights in noise-induced hearing loss: a literature review of the underlying mechanism, pathophysiology, asymmetry, and management options’, *Journal of Otolaryngology-Head & Neck Surgery*, vol. 46, no. 1, pp. 1–15. https://doi.org/10.1186/s40463-017-0219-x

Levine, RA 2003, ‘Hearing loss and tinnitus’, in MA Samuels & SK Feske (eds.), *Office practice of neurology*, 2nd edn., Churchill Livingstone, New York, pp. 87–102.

Lie, A, Engdahl, B, Hoffman, HJ, Li, CM & Tambs, K 2017, ‘Occupational noise exposure, hearing loss, and notched audiograms in the HUNT Nord-Trøndelag hearingloss study, 1996–1998’, *Laryngoscope*, vol. 127, no. 6, pp. 1450. https://doi.org/10.1002/lary.26256

Lie, A, Skogstad, M, Johnsen, TS, Engdahl, B & Tambs, K 2015, ‘The prevalence of notched audiograms in a cross-sectional study of 12,055 railway workers’, *Ear and Hearing*, vol. 36, no. 3, a129. https://doi.org/10.1097/AUD.0000000000000129

Majumder, J, Patel, RC, Kotadiya, S & Shah, P 2018, ‘Hearing threshold status and risk estimate of hearing impairment among administrative workforce’, *Indian Journal of Occupational and Environmental Medicine*, vol. 22, no. 1, pp. 11–16. https://doi.org/10.4103/ijoem.IJOEM_22_18

Manchaiah, VKC 2011, *New degree/severity classification for the audiogram: What do audiologists have to say?*, Audiology Online, viewed 10 January 2021, <https://www.audiologyonline.com/articles/new-degree-severity-classification-for-810>

Manning, WG & Pillay, M 2020, ‘A critical analysis of the current South African occupational health law and hearing loss’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a694. https://dx.doi.org/10.4102%2Fsajcd.v67i2.694

Margolis, RH & Saly, GL 2007, ‘Toward a standard description of hearing loss’, *International Journal of Audiology*, vol. 46, no. 12, pp. 746–758. https://doi.org/10.1080/14992020701572652

McBride, DI & Williams, S 2001, ‘Audiometric notch as a sign of noise induced hearing loss’, *Occupational Environmental Medicine*, vol. 58, no. 1, pp. 46–51. https://doi.org/10.1136/oem.58.1.46

Metidieri, MM, Rodrigues, HF, Filho, FJ, Ferraz, DP, Neto, AF & Torres, S 2013, ‘Noise-induced hearing loss (NIHL): Literature review with a focus on occupational medicine’, *International Archives of Otorhinolaryngology*, vol. 17, no. 2, pp. 208–212. https://doi.org/10.7162/S1809-97772013000200015

Miyakita, T & Miura, H 1986, ‘A tentative proposal for classification of audiograms in noise-induced deafness: Relationship between audiogram and subjective complaints in noise-exposed workers’, *International Archives of Occupational and Environmental Health*, vol. 57, no. 3, pp. 173–183. https://doi.org/10.1007/BF00405786

Moepeng, M, Soer, M & Vinck, B 2017, ‘Distortion product otoacoustic emissions as a health surveillance technique for hearing screening in workers in the steel manufacturing industry’, *Occupational Health Southern Africa*, vol. 23, no. 5, pp. 8–13.

Momm, W & Geiecker, O n.d., ‘Disability and work’, in *Encyclopaedia of occupational health and safety*, International Labour Office, viewed 10 July 2017, <http://www.ilocis.org/documents/chpt17e.htm>

Moore, BCJ 2016, 'A review of the perceptual effects of hearing loss for frequencies above 3 kHz', *International Journal of Audiology*, vol. 55, no. 12, pp. 707–714. https://doi.org/10.1080/14992027.2016.1204565

Moroe, N, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise–induced hearing loss in the mining sector in Africa: A systematic review – 1994 to 2016', *Noise & Vibration Worldwide*, vol. 49, no. 5, pp. 181–190. https://doi.org/10.1177/0957456518781860

Moroe, NF 2020, 'Occupational noise-induced hearing loss in South African large-scale mines: Exploring hearing conservation programmes as complex interventions embedded in a realist approach', *International Journal of Occupational Safety and Ergonomics*, vol. 26, no. 4, pp. 753–761. https://doi.org/10.1080/10803548.2018.1498183

Moroe, NF & Khoza-Shangase, K 2018, 'Management of occupational noise induced hearing loss in the mining sector in South Africa: Where are the audiologists?', *Journal of Occupational Health*, vol. 60, no. 5, pp. 376–382. https://doi.org/10.1539/joh.2018-0020-OA

Musiba, Z 2015, 'The prevalence of noise induced hearing loss among Tanzanian miners', *Occupational Medicine*, vol. 65, no. 5, pp. 386–390. https://doi.org/10.1093/occmed/kqv046

Musiba, Z 2020, 'Classification of audiograms in the prevention of noise-induced hearing loss: A clinical perspective', *South African Journal of Communication Disorders*, vol. 67, no. 2, a691. https://doi.org/10.4102/sajcd.v67i2.691

National Health and Nutrition Examination Survey 2003, *Audiometry procedures manual*, Centers for Disease Control and Prevention, viewed 10 January 2021, <https://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/au.pdf>

Nondahl, DM, Shi, X, Cruickshanks, KJ, Dalton, DS, Tweed, TS, Wiley, TL & Carmichael, LL 2009, 'Notched audiograms and noise exposure history in older adults', *Ear and Hearing*, vol. 30, no. 6, pp. 696–703. https://doi.org/10.1097/AUD.0b013e3181b1d418

Ntlhakana, L, Nelson, G & Khoza-Shangase, K 2020, 'Estimating miners at risk for occupational noise-induced hearing loss: A review of data from a South African platinum mine', *South African Journal of Communication Disorders*, vol. 67, no. 2, pp. 1–8. https://doi.org/10.4102/sajcd.v67i2.677

Osei-Lah, V & Yeoh, LH 2010, 'High frequency audiometric notch: an outpatient clinic survey', *International Journal of Audiology*, vol. 49, no. 2, pp. 95–98. https://doi.org/10.3109/14992020903300423

Rabinowitz, PM 2012, 'The public health significance of noise-induced hearing loss', in CG Le Prell, D Henderson, RR Fay et al. (eds.), *Noise-induced hearing loss*, Springer, New York, pp. 13–25.

Redelinghuis, L 2016, 'Guidance note for the implementation of standard threshold shift (STS) in the medical surveillance of noise induced hearing loss', *Health and Safety, Newflashes*, viewed 14 January 2021, <http://www.shangoni.co.za/guidance-note-implementation-standard-threshold-shift-medical-surveillance-noise-induced-hearing-loss/>

Schaafsma, F, Benke, G & Radi, S 2010, *Noise induced hearing loss and audiometry*, Monash University Centre for Occupational and Environmental Health, viewed 14 January 2021, <https://research.iscrr.com.au/__data/assets/pdf_file/0003/297138/noise-induced-hearing-loss-and-audiometry.pdf>

Schlauch, RS & Nelson, P 2014, 'Puretone evaluation', in *Handbook of clinical audiology*, 7th edn., Taylor and Francis Inc, New York, pp. 29–47.

Staab, W 2014, *Before the audiogram*, Hearing Health and Technology Matters, viewed 10 January 2021, <https://hearinghealthmatters.org/waynesworld/2014/audiogram/>

Vd Drift, JFC, Brocaar, MP & v. Zanten, GA 1988, 'Brainstem response audiometry: II. Classification of hearing loss by discriminant analysis', *Audiology*, vol. 27, no. 5, pp. 271–278. https://doi.org/10.3109/00206098809081598

Veith, T 2021, 'The audiologist's role in university hearing conservation programs: Gaps and opportunities in US universities [Original Article]', *Noise and Health*, vol. 23, no. 108, pp. 11–20. https://doi.org/10.4103/nah.NAH_60_19

Vogel, DA, McCarthy, PA, Bratt, GW & Brewer, C 2007, 'The clinical audiogram: Its history and current use', *Communicative Disorders Review*, vol. 1, no. 2, pp. 81–94.

Wilson, RH & McArdle, R 2013, 'Characteristics of the audiometric 4,000 Hz notch (744,553 veterans) and the 3,000, 4,000, and 6,000 Hz notches (539,932 veterans)', *Journal of Rehabilitation Research and Development*, vol. 50, no. 1, pp. 111–132. https://doi.org/10.1682/jrrd.2011.11.0225

Zwislocki, JJ & Feldman, AS 1970, 'Acoustic impedance of pathological ears', *American Speech-Language Hearing Association Monogram*, vol. 15, pp. 1–42.

Chapter 6

Agarwal, G, Nagpure, P, Pal, K, Kaushal, A & Kumar, M 2015, 'Audiometric notching at 4 kHz: Good screening test for assessment of early onset of occupational hearing loss', *Indian Journal of Otology*, vol. 21, no. 4, pp. 270–273. https//doi.org/10.4103/0971-7749.164552

Ali, D & Frimpong, S 2020, 'Artificial intelligence, machine learning and process automation: Existing knowledge frontier and way forward for mining sector', *Artificial Intelligence Review*, vol. 53, no. 8, pp. 6025–6042. https://doi.org/10.1007/s10462-020-09841-6

Amedofu 2007, 'Effectiveness of hearing conservation program at a large surface gold mining company in Ghana', *African Journal of Health Sciences*, vol. 14, no. 1, pp. 49–53. https://doi.org/10.4314/ajhs.v14i1.30846

Angliss, S 1998, *Sound level meter*, Garland Publishing, New York.

Azizi, MH 2010, 'Occupational noise-induced hearing loss', *Academy of Medical Sciences of the IR*, vol. 1, no. 3, pp. 116–123.

Bara, AC & Arber, S 2009, 'Working shifts and mental health: Findings from the British Household Panel Survey (1995–2005)', *Scandinavian Journal of Work, Environment & Health*, vol. 35, no. 5, pp. 361–367. https://doi.org/10.5271/sjweh.1344

Berger, EH, Royster, LH, Royster, JD, Driscoll, DP & Layne, M 2003, *Noise control and hearing conservation: Why do it?*, 5th edn., American Industrial Hygiene Association, Falls Church.

Beyan, AC, Demiral, Y, Cimrin, AH & Ergor, A 2016, 'Call centers and noise-induced hearing loss', *Noise & Health*, vol. 18, no. 81, pp. 113–116. https://doi.org/10.4103/1463-1741.178512

Biabani, A, Aliabadi, M, Golmohammadi, R & Farhadian, M 2017, 'Individual fit testing of hearing protection devices based on microphone in real ear', *Safety and Health at Work*, vol. 8, no. 4, pp. 364–370. https://doi.org/10.1016/j.shaw.2017.03.005

Bloem, J, Van Doorn, M, Duivestein, S, Excoffier, D, Maas, R & Van Ommeren, E 2014, 'The Fourth Industrial Revolution', *Things Tighten*, vol. 8, pp. 11–15. https://www.sogeti.com/globalassets/global/special/sogeti-things3en.pdf

Brauch, R 2017, 'Tech advances are reinventing hearing conservation programs: Open your ears', *Industrial Safety and Hygiene News*, viewed 10 January 2021, <https://www.ishn.com/articles/105847-tech-advances-are-reinventing-hearing-conservation-programs>

Chen, YK 2012, 'Challenges and opportunities of internet of things', in *17th Asia and South Pacific Design Automation Conference*, IEEE, January, Sydney, pp. 383–388.

Chu, S & Majumdar, A 2012, 'Opportunities and challenges for a sustainable energy future', *Nature*, vol. 488, no. 7411, pp. 294–303. https://doi.org/10.1038/nature11475

Dimitrieska, S, Stankovsk, A & Efremova, T 2018, 'The Fourth Industrial Revolution: Advantagesand disadvantages', *Economics and Management*, vol. 14, no. 2, pp. 182–187. https://ideas.repec.org/a/neo/journl/v14y2018i2p182-187.html

Glibert, D 1922, 'Influence of industrial noises', *Journal of Industrial Hygiene*, vol. 3, pp. 264–275.

Hager, L 2011, 'Fit-testing hearing protectors: An idea whose time has come', *Noise and Health*, vol. 13, no. 51, pp. 147–151. https://doi.org/10.4103/1463-1741.77217

Hedeen, RA 1980, *Compendium of materials for noise control (No. 80–116)*, Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Robert A. Taft Laboratories, viewed 10 December 2017, <https://www.cdc.gov/niosh/docs/80-116/pdfs/80-116.pdf?id=10.26616/NIOSHPUB80116>

Heywood, JB 1988, *Internal combustion engine fundamentals*, 1st edn., McGraw-Hill, Inc, New York.

Hong, O, Kerr, MJ, Poling, GL & Dhar, S 2013, 'Understanding and preventing noise-induced hearing loss', *Disease-a-Month*, vol. 59, no. 4, pp. 110–118. https://doi.org/10.1016/j.disamonth.2013.01.002

Huizingh, EKRE 2011, 'Open innovation: State of the art and future perspectives', *Technovation*, vol. 31, no. 1, pp. 2–9. https://doi.org/10.1016/j.technovation.2010.10.002

Hull, J 1994, 'The second industrial revolution and the staples frontier in Canada: Rethinking knowledge and history', *Scientia Canadensis: Canadian Journal of the History of Science, Technology and Medicine/Scientia Canadensis: Revue canadienne d'histoire des sciences, des techniques et de la médecine*, vol. 18, no. 1, pp. 22–37. https://doi.org/10.7202/800373aradresse copiéeune erreur s'est produite

Jia, Y, Lu, Y, Wu, K, Lin, Q, Shen, W, Zhu, M, Huang, S & Chen, J 2013, 'Does night work increase the risk of breast cancer? A systematic review and meta-analysis of epidemiological studies', *Cancer Epidemiology*, vol. 37, no. 3, pp. 197–206. https://doi.org/10.1016/j.canep.2013.01.005

Kane-Berman, J 2017, *Diamonds and all that: The contribution of mining to South Africa: Mining in SA: Then, now, and into the future – IRR*, viewed 15 March 2018, <https://www.polity.org.za/article/diamonds-and-all-that-the-contribution-of-mining-to-south-africa-2017-02-16>

Khan, KM, Bielko, SL & McCullagh, MC 2018, 'Efficacy of hearing conservation education programs for youth and young adults: A systematic review', *BMC Public Health*, vol. 18, no. 1, p. 1286. https://doi.org/10.1186/s12889-018-6198-7

Khoza-Shangase, K 2022, 'Preventive audiology: Ramping up efforts towards an ear and hearing healthy nation', ed. K Khoza-Shangase, *Preventive audiology: An African perspective,* AOSIS Books, Cape Town, pp. 1–20. https://doi.org/10.4102/aosis.2022.BK209.01

Khoza-Shangase, K & Moroe, NF 2020a, 'Risk versus benefit: Should not audiologists assess this in the context of occupational noise-induced hearing loss in the mining industry?', *South African Journal of Communication Disorders*, vol. 67, no. 2, a671. https://doi.org/10.4102/sajcd.v67i2.671

Khoza-Shangase, K & Moroe, N 2020b, 'South African hearing conservation programmes in the context of tele-audiology: A scoping review', *South African Journal of Communication Disorders*, vol. 67, no. 2, a670. https://doi.org/10.4102/sajcd.v67i2.670

Khoza-Shangase, K, Moroe, NF & Edwards, A 2020, 'Occupational hearing loss in Africa: An interdisciplinary view of the current status', *South African Journal of Communication Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Knutsson, A & Kempe, A 2014, 'Shift work and diabetes: A systematic review', *Chronobiology International*, vol. 31, no. 10, pp. 1146–1451. https://doi.org/10.3109/07420528.2014.957308

Konya, A 2020, *Blasting through the ages: A brief history of drilling*, viewed 10 February 2021, <https://www.pitandquarry.com/blasting-through-the-ages-a-brief-history-of-drilling/>

Koo, YS, Song, JY, Joo, EY, Lee, HJ, Lee, E, Lee, SK & Jung, KY 2016, 'Outdoor artificial light at night, obesity, and sleep health: Cross-sectional analysis in the KoGES study', *Chronobiology International*, vol. 33, no. 3, pp. 301–314. https://doi.org/10.3109/07420528.2016.1143480

Lasi, H, Fettke, P, Kemper, HG, Feld, T & Hoffmann, M 2014, 'Industry 4.0', *Business & Information Systems Engineering*, vol. 6, no. 4, pp. 239–242. https://doi.org/10.1007/s12599-014-0334-4

Le, QT, Pedro, A & Park, CS 2015, 'A social virtual reality based construction safety education system for experiential learning', *Journal of Intelligent & Robotic Systems*, vol. 79, no. 3, pp. 487–506. https://doi.org/10.1007/s10846-014-0112-z

Lee, HY, Kim, MS, Kim, O, Lee, IH & Kim, HK 2016, 'Association between shift work and severity of depressive symptoms among female nurses: The Korea Nurses' Health Study', *Journal of Nursing Management*, vol. 24, no. 2, pp. 192–200. https://doi.org/10.1111/jonm.12298

Lee, M, Yun, JJ, Pyka, A, Won, D, Kodama, F, Schiuma, G, Park, HS, Jeon, J, Park, K, Jung, K, Yan, MR, Lee, S & Zhao, X 2018, 'How to respond to the fourth industrial revolution, or the second information technology revolution? Dynamic new combinations between technology, market, and society through open innovation', *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 4, no. 3, a21. https://doi.org/10.3390/joitmc4030021

Maynard, AD 2015, 'Navigating the fourth industrial revolution', *Nature Nanotechnology*, vol. 10, no. 12, pp. 1005–1006. https://doi.org/10.1038/nnano.2015.286

Michaud, A 2019, *Mining and the Fourth Industrial Revolution: Expectations and challenges*, viewed 10 January 2021, <https://www.angloamerican.com/futuresmart/stories/our-industry/industry-trends/mining-and-the-fourth-industrial-revolution-expectations-and-challenges>

Min, J, Kim, Y, Lee, S, Jang, TW, Kim, I & Song, J 2019, 'The Fourth Industrial Revolution and its impact on occupational health and safety, worker's compensation and labor conditions', *Safety and Health at Work*, vol. 10, no. 4, pp. 400–408. https://doi.org/10.1016/j.shaw.2019.09.005

Mirza, R, Kirchner, DB, Dobie, RA, Crawford, J & ACOEM Task Force on Occupational Hearing Loss 2018, 'Occupational noise-induced hearing loss', *Journal of Occupational and Environmental Medicine*, vol. 60, no. 9, pp. 498–501. https://doi.org/10.1097/JOM.0000000000001423

Moore, PV & Lusk, SL 1997, 'Noise exposures: Effects on hearing and prevention of noise induced hearing loss', *AAOHN Journal*, vol. 45, no. 8, pp. 397–410. https://doi.org/10.1177/216507999704500806

Moroe, NF 2020, 'Occupational noise-induced hearing loss in South African large-scale mines: Exploring hearing conservation programmes as complex interventions embedded in a realist approach', *International Journal of Occupational Safety and Ergonomics*, vol. 26, no. 4, pp. 753–761. https://doi.org/10.1080/10803548.2018.1498183

Moroe, NF & Khoza-Shangase, K 2020, 'Recent advances in hearing conservation programmes: A systematic review', *South African Journal of Communication Disorders*, vol. 67, no. 2, a675. https://doi.org/10.4102/sajcd.v67i2.675

Moroe, N, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise–induced hearing loss in the mining sector in Africa: A systematic review–1994 to 2016', *Noise & Vibration Worldwide*, vol. 49, no. 5, pp. 181–190. https://doi.org/10.1177/0957456518781860

Moroe, N, Khoza-Shangase, K, Madahana, M & Nyandoro, O 2019, 'A proposed preliminary model for monitoring hearing conservation programmes in the mining sector in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 119, no. 7, pp. 671–679. https://doi.org/10.17159/2411-9717/18/016/2019

Moroe, NF, Khoza-Shangase, K, Madahana, M & Nyandoro, O 2020, 'Feedback-based noise management matrix in action', *South African Journal of Communication Disorders*, vol. 67, no. 2, a678. https://doi.org/10.4102/sajcd.v67i2.678

Nair, DC 2014, 'Noise-induced hearing loss', *InnovAiT*, vol. 7, no. 4, pp. 204–208. https://doi.org/10.1177/1755738013518903

National Academy of Engineering 2010, *Control of hazardous noise*, The National Academies Press, Washington.

National Institute for Occupational Safety and Health (NIOSH) 2016, *Hierarchy of controls*, viewed 03 January 2018, <https://www.cdc.gov/niosh/topics/hierarchy/>

Nelson, DI, Nelson, RY, Concha-Barrientos, M & Fingerhut, M 2005, 'The global burden of occupational noise-induced hearing loss', *American Journal of Industrial Medicine*, vol. 48, no. 6, pp. 446–458. https://doi.org/10.1002/ajim.20223

Ntlhakana, L & Khoza-Shangase, K 2022, 'Machine learning models: Predictive tools for occupational noise-induced hearing loss in the South African mining industry', ed. K Khoza-Shangase, *Preventive audiology: An African perspective,* AOSIS Books, AOSIS Publishing (Pty) Ltd, Cape Town, pp. 253–266. https://doi.org/10.4102/aosis.2022.BK209.13

Ntlhakana, L, Nelson, G & Khoza-Shangase, K 2020, 'Estimating miners at risk for occupational noise-induced hearing loss: A review of data from a South African platinum mine', *South African Journal of Communication Disorders*, vol. 67, no. 2, a677. https://doi.org/10.4102/sajcd.v67i2.677

Ntlhakana, L, Nelson, G, Khoza-Shangase, K & Dorkin, E 2021, 'Occupational hearing loss for platinum miners in South Africa: a case study of data sharing practices and ethical challenges in the mining industry', *International Journal of Environmental Research and Public Health*, vol. 19, no. 1, a1. https://doi.org/10.3390/ijerph19010001

Ntlhakana, L, Nelson, G, Khoza-Shangase, K & Maposa, I 2021, 'Predicting standard threshold shifts for occupational hearing loss among miners at a large-scale platinum mine in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 121, no. 8, pp. 1–8. https://doi.org/10.17159/2411-9717/1318/2021

Petrillo, A, De Felice, F, Cioffi, R & Federico Zomparelli, F 2018, 'Fourth Industrial Revolution: Current practices, vhallenges, and opportunities', eds. A Petrillo, R Cioffi & F De Felice, *Digital transformation in smart manufacturing*, IntechOpen, Vienna.

Ramazzini, B 1964, *Diseases of workers (De morbis artificum, 1713)*, transl. WC Wright, Hafner Publishing, New York.

Rejeb, A, Keogh, JG, Leong, GK & Treiblmaier, H 2021, 'Potentials and challenges of augmented reality smart glasses in logistics and supply chain management: a systematic literature review', *International Journal of Production Research*, vol. 59, no. 12, pp. 3747–3776.

Rupprecht, SM 2017, 'Bench mining utilizing manual labour and mechanized equipment: A proposed mining method for artisanal small-scale mining in Central Africa', *The Southern African Institute of Mining and Metallurgy*, vol. 117, pp. 25–31. https://doi.org/10.17159/2411-9717/2017/v117n1a5

Sánchez, F & Hartlieb, P 2020, 'Innovation in the mining industry: Technological trends and a case study of the challenges of disruptive innovation', *Mining, Metallurgy & Exploration*, vol. 37, pp. 1385–1399. https://doi.org/10.1007/s42461-020-00262-1

Santana, C, Barros, J & Junior, H 2014, 'Analysis of vibration and noise of an internal combustion engine by application of test and experimental analysis of the frequency spectrum', *XXI Simpósio Internacional de Engenharia Automotiva*, viewed 10 February 2020, <https://www.researchgate.net/publication/269234023_Analysis_of_Vibration_and_Noise_of_an_Internal_Combustion_Engine_by_Application_of_Test_and_Experimental_Analysis_of_the_Frequency_Spectrum>

Schwab, K 2016, *The Fourth Industrial Revolution: What it means, how to respond foreign affairs*, viewed 10 January 2021, <https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/>

Schwab, K 2019, *Globalization 4.0: A new architecture for the Fourth Industrial Revolution foreign affairs*, viewed 10 January 2021, <https://www.foreignaffairs.com/articles/world/2019-01-16/globalization-40>

Smit, AC & Mji, A 2012, 'Assessment of numeracy levels of mine workers in South African chrome mine', *Numeracy*, vol. 5, no. 2, a4. https://doi.org/10.5038/1936-4660.5.2.4

Suter, AH 2002, 'Construction noise: Exposure, effects, and the potential for remediation: A review and analysis', *AIHA Journal*, vol. 63, no. 6, pp. 768–789. https://doi.org/10.1080/15428110208984768

Sutherland, E 2020, 'The Fourth Industrial Revolution: The case of South Africa', *Politikon*, vol. 47, no. 2, pp. 233–252. https://doi.org/10.1080/02589346.2019.1696003

Thackrah, CT 1832, *The effects of arts, trades, and professions: And of civic states and habits of living, on health and longevity: With suggestions for the removal of many of the agents which produce disease, and shorten and duration of life*, Longman, Rees, Orme, Brown, Green & Longman, viewed 10 July 2020, <https://wellcomecollection.org/works/pp7msgx5>

Thurston, FE 2013, 'The worker's ear: A history of noise-induced hearing loss', *American Journal of Industrial Medicine*, vol. 56, no. 3, pp. 367–377. https://doi.org/10.1002/ajim.22095

Toffler, A & Alvin, T 1980, *The third wave*, vol. 484, Bantam Books, viewed 16 January 2020, <https://ia801301.us.archive.org/26/items/TheThirdWave-Toffler/The-Third-Wave_-_Toffler.pdf>

Touitou, Y, Reinberg, A & Touitou, D 2017, 'Association between light at night, melatonin secretion, sleep deprivation, and the internal clock: Health impacts and mechanisms of circadian disruption', *Life Sciences*, vol. 173, pp. 94–106. https://doi.org/10.1016/j.lfs.2017.02.008

Vyas, MV, Garg, AX, Iansavichus, AV, Costella, J, Donner, A, Laugsand, LE, Janszky, I, Mrkobrada, M, Parraga, G & Hackam, DG 2012, 'Shift work and vascular events: Systematic review and meta-analysis', *BMJ*, vol. 345, a4800. https://doi.org/10.1136/bmj.e4800

Xu, M, David, J & Kim, SH 2018, 'The fourth industrial revolution: Opportunities and challenges', *International Journal of Financial Research*, vol. 9, no. 2, pp. 90–95. https://doi.org/10.5430/ijfr.v9n2p90

Zhou, J, Shi, Z, Zhou, L, Hu, Y & Zhang, M 2020, 'Occupational noise-induced hearing loss in China: A systematic review and meta-analysis', *BMJ Open*, vol. 10, no. 9, a039576. https://doi.org/10.1136/bmjopen-2020-039576

Chapter 7

Ahamed, NU, Yusof, Z, Hamedon, Z, Rabbi, MF, Sikandar, T, Palaniappan, R et al. 2016, 'Fuzzy logic controller design for intelligent drilling system', in *2016 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS)*, pp. 208–213, IEEE, October, viewed 15 January 2020, <https://ieeexplore.ieee.org/document/7885316>

Alan, M 2019, *Roadmap to the digital mine: Resolute mining*, viewed 16 November 2020, <https://www.youtube.com/watch?v=TzoMOFUGb6o>

Ali, D & Frimpong, S 2020, 'Artificial intelligence, machine learning and process automation: Existing knowledge frontier and way forward for mining sector', *Artificial Intelligence Review*, vol. 53, no. 8, pp. 6025–6042. https://doi.org/10.1007/s10462-020-09841-6

Amini, H, Gholami, R, Monjezi, M, Torabi, SR & Zadhesh, J 2012, 'Evaluation of flyrock phenomenon due to blasting operation by support vector machine', *Neural Computing and Applications*, vol. 21, no. 8, pp. 2077–2085. https://doi.org/10.1007/s00521-011-0631-5

Awuah-Offei, K & Rehman, AU 2018, 'Investigating the information diffusion potential of social media networks', *Mining Engineering Society for Mining, Metallurgy and Exploration*, vol. 70, no. 4, pp. 28–32.

Azizi, MH 2010, 'Occupational noise-induced hearing loss', *The International Journal of Occupational and Environmental Medicine*, vol. 1, no. 3, pp. 116–123.

Babich, DR & Bauer, ER 2006, 'Summary of longwall and continuous miner section noise studies in underground coal mines', *National Institute for Occupational Safety and Health (NIOSH)*, Pittsburgh Research Laboratory, Pittsburgh.

Balch, O 2019, 'What a Mali mine teaches us about the future of work', *Racontour*, viewed 11 January 2021, <https://www.raconteur.net/business-innovation/mining-automation-mali>

Barnewold, L & Lottermoser, BG 2020, 'Identification of digital technologies and digitalisation trends in the mining industry', *International Journal of Mining Science and Technology*, vol. 30, no. 6, pp. 747–757. https://doi.org/10.1016/j.ijmst.2020.07.003

Bellamy, D & Pravica, L 2011, 'Assessing the impact of driverless haul trucks in Australian surface mining', *Resources Policy*, vol. 36, no. 2, pp. 149–158. https://doi.org/10.1016/j.resourpol.2010.09.002

Bies, DH, Hansen, CH & Campbell, RH 1996, 'Engineering noise control', *Journal of the Acoustical Society of America*, vol. 100, p. 1279. https://doi.org/10.1121/1.416038

Black Livingston, J, Stanton, A & Nussbaum, A 2018, *The benefits and pitfalls of mining automation*, viewed 10 January 2020, <https://www.mining.com/web/benefits-pitfalls-mining-automation/>

Bradley, DA & Seward, DW 1998, 'The development, control and operation of an autonomous robotic excavator', *Journal of Intelligent and Robotic Systems*, vol. 21, no. 1, pp. 73–97. https://doi.org/10.1023/A:1007932011161

Bołoz, Ł & Biały, W 2020, 'Automation and robotization of underground mining in Poland', *Applied Sciences*, vol. 10, no. 20, a7221. https://doi.org/10.3390/app10207221

Bullock, DM & Oppenheim, IJ 1989, 'A laboratory study of force-cognitive excavation', in *Proceedings of Sixth International Symposium on Automation and Robotics in Construction*, pp. 64–72, viewed 19 July 2020, <https://www.researchgate.net/publication/239665568_A_Laboratory_Study_of_Force-Cognitive_Excavation>

Bügler, M, Borrmann, A, Ogunmakin, G, Vela, PA & Teizer, J 2017, 'Fusion of photogrammetry and video analysis for productivity assessment of earthwork processes', *Computer-Aided Civil and Infrastructure Engineering*, vol. 32, no. 2, pp. 107–123. https://doi.org/10.1111/mice.12235

Burger, NDL, Von Wielligh, AJ, De Wet, PR, Otterman, RW & Steyn, JL 2004, 'Design and development of a low noise rockdrill', *The Journal of the South African Institute of Mining and Metallurgy*, pp. 403–410. https://www.saimm.co.za/Journal/v104n07p403.pdf

Cascio, WF & Montealegre, R 2016, 'How technology is changing work and organizations', *Annual Review of Organizational Psychology and Organizational Behavior*, vol. 3, pp. 349–375. https://psycnet.apa.org/doi/10.1146/annurev-orgpsych-041015-062352

Chi, S & Caldas, CH 2011, 'Automated object identification using optical video cameras on construction sites', *Computer-Aided Civil and Infrastructure Engineering*, vol. 26, no. 5, pp. 368–380. https://doi.org/10.1111/j.1467-8667.2010.00690.x

Chuhan-Pole, P, Dabalen, AL & Land, BC 2017, *Mining in Africa: are local communities better off?*, World Bank Publications, viewed 10 September 2018, <https://openknowledge.worldbank.org/handle/10986/26110>

Cloete, K 2019, *Mining weekly*, viewed 10 January 2021, <https://m.miningweekly.com/article/sandvik-resolute-gear-up-for-the-fully-automated-syama-gold-mine-2019-02-07/rep_id:3861>

Cloete, D 2020, *SADC futures of mining: Implications of large-scale EV adoption*, viewed 10 January 2021, <https://www.africaportal.org/publications/sadc-futures-mining-implications-large-scale-ev-adoption/>

Corke, PI, Winstanley, GJ & Roberts, JM 1997, 'Dragline modelling and corkecontrol', *Proceedings of International Conference on Robotics and Automation*, vol. 2, pp. 657–662.

Coulson, M 2012, *The history of mining: The events, technology and people involved in the industry that forged the modern world*, Harriman House Limited, viewed 10 July 2020, <https://www.perlego.com/book/1415715/the-history-of-mining-the-events-technology-and-people-involved-in-the-industry-that-forged-the-modern-world-pdf>

Cosbey, A, Mann, H, Maennling, N, Toledano, P, Geipel, J & Brauch, MD 2016, *Mining a mirage: Reassessing the shared-value paradigm in light of the technological advances in the mining sector*, viewed 20 March 2018, <https://www.iisd.org/publications/mining-mirage-reassessing-shared-value-paradigm-light-technological-advances-mining>

Dalal, N & Triggs, B 2005, 'Histograms of oriented gradients for human detection', *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, vol. 1, pp. 886–893. https://doi.org/10.1109/CVPR.2005.177

Deloitte 2018, *The future of mining in Africa: Navigating a revolution*, viewed 10 March 2020, <https://www2.deloitte.com/content/dam/Deloitte/za/Documents/energy-resources/za_Future_of_mining.pdf>

Giardino, DA, Bobick, TG & Marraccini, LC 1977, *Noise control of an underground continuous miner, Auger-Type*, viewed 16 January 2021, <https://arlweb.msha.gov/techsupp/pshtcweb/ptadirs/IR1056.pdf>

General Kinematics 2020, *A brief history of mining: The advancement of mining techniques and technology*, viewed 10 January 2021, <https://www.generalkinematics.com/blog/a-brief-history-of-mining-and-the-advancement-of-mining-technology/>

Geschwindt, T 2021, *Mining's new horizons Risk and reward at the dawn of the Fourth Industrial Revolution*, S-RM, viewed 10 November 2021, <https://insights.s-rminform.com/mining-risk-fourth-industrial-revolution>

Girmscheid, G & Wälti, R 2001, 'High performance drill and blast method-progress in efficiency through industrialized backup systems and process configuration', in *Progress in tunnelling* *after 2000: proceedings of the AITES-ITA 2001 World Tunnel Congress*, Milan, 10th–13th June 2001, pp. 163–171, Pàtron, viewed 10 July 2020, <https://www.research-collection.ethz.ch/handle/20.500.11850/372338>

Gocho, T, Yamabe, N, Hamaguchi, T, Hitomi, S, Ono, T, Oshima, H. et al. 1992, 'Automatic wheel-loader in asphalt plant', *9th ISARC International Symposium on Automation and Robotics in Construction, International Association for Automation and Robotics in Construction* (IAARC), pp. 803–812, viewed 16 July 2020, <https://www.iaarc.org/publications/proceedings_of_the_9th_isarc/automatic_wheelloader_in_asphalt_plant.html>

Golparvar-Fard, M, Peña-Mora, F & Savarese, S 2015, 'Automated progress monitoring using unordered daily construction photographs and IFC-based building information models', *Journal of Computing in Civil Engineering*, vol. 29, no. 1, a04014025. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000205

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', *The Journal of the Southern African Institute of Mining and Metallurgy*, vol. 114, pp. 923–928. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532014001100010&lng=en&nrm=iso

Gustafson, A 2011, *Automation of load haul dump machines, research report*, Luleå University of Technology, viewed 12 January 2021, <https://www.diva-portal.org/smash/get/diva2:995534/FULLTEXT01.pdf>

Hainsworth, DW 1996, *Dragline automation in Australian Coal Association Research Program Project Report (C3007),* viewed 16 July 2020, <https://www.acarp.com.au/abstracts.aspx?repId=C3007>

Hashmi, K, Graham, ID & Mills, B 2000, 'Fuzzy logic based data selection for the drilling process', *Journal of Materials Processing Technology*, vol. 108, no. 1, pp. 55–61. https://doi.org/10.1016/S0924-0136(00)00597-5

Huang, XD & Bernold, LE 1993, 'Robotic rock handling during backhoe excavation. Automation and Robotics in construction', *Proceedings of the 10th ISARC*, viewed 14 July 2020, <https://www.iaarc.org/publications/fulltext/Robotic_rock_handling_during_backhoe_excavation.PDF>

Humphreys, D 2020, 'Mining productivity and the fourth industrial revolution', *Mineral Economics*, vol. 33, no. 1, pp. 115–125. https://doi.org/10.1007/s13563-019-00172-9

Jacobs, J & Webber-Youngman, RCW 2017, 'A technology map to facilitate the process of mine modernization throughout the mining cycle', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 117, no. 7, pp. 636–648. https://doi.org/10.17159/2411-9717/2017/v117n7a5

Ji, P, Song, A., Xiong, P., Yi, P., Xu, X & Li, H 2017, 'Egocentric-vision based hand posture control system for reconnaissance robots', *Journal of Intelligent and Robotic Systems*, vol. 87, pp. 583–599. https://doi.org/10.1007/s10846-016-0440-2

Kaplan, D 2011, *South African mining equipment and related services: Growth constraints and policy (No 5)*, MMCP Discussion Paper, viewed 12 January 2021, <http://www.cssr.uct.ac.za/sites/default/files/image_tool/images/256/files/pubs/MMCP%20Paper%205_0.pdf>

Khandelwal, M & Monjezi, M 2013, 'Prediction of backbreak in open-pit blasting operations using the machine learning method', *Rock Mechanics and Rock Engineering*, vol. 46, no. 2, pp. 389–396. https://doi.org/10.1007/s00603-012-0269-3

Khoza-Shangase, K, Moroe, N & Edwards, A 2020, 'Occupational hearing loss in Africa: An interdisciplinary view of the current status', *South African Journal of Communication Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Kock, JFW 2013, 'Hearing protection in mines: Evaluating the noise Clipper® Custom made hearing protection device', doctoral dissertation, University of Pretoria, viewed 11 January 2021, <https://repository.up.ac.za/bitstream/handle/2263/25539/dissertation.pdf;sequence=1>

Kwiri, J 2018, 'Concept development of a smart rock engineering system for real-time decision-making and risk minimization in deep level hard rock mines: a digital mining approach', doctoral dissertation, viewed 11 January 2021, <http://wiredspace.wits.ac.za/handle/10539/26622>

Lovells, H 2018, *The benefits and pitfalls of mining automation*, viewed 10 January 2021, <https://www.mining.com/web/benefits-pitfalls-mining-automation/>

Mabena, S 2020, *Mines speeding up automation amid virus threat*, viewed 16 January 2021, <https://citizen.co.za/premium/2267275/mines-speeding-up-automation-amid-virus-threat/>

Madahana, MC, Ekoru, JE, Mashinini, TL & Nyandoro, OT 2019a, 'Noise level policy advising system for mine workers', *IFAC-PapersOnLine*, vol. 52, no. 14, pp. 249–254. https://doi.org/10.1016/j.ifacol.2019.09.195

Madahana, MC, Ekoru, JE & Nyandoro, OT 2019b, 'Smart automated noise policy monitoring and feedback control system for mining application', *IFAC-PapersOnLine*, vol. 52, no. 14, pp. 177–182. https://doi.org/10.1016/j.ifacol.2019.09.184

Madahana, MC, Ekoru, JE, Mashinini, TL & Nyandoro, OT 2019c, 'Mine workers threshold shift estimation via optimization algorithms for deep recurrent neural networks', *IFAC-PapersOnLine*, vol. 52, no. 14, pp. 117–122. https://doi.org/10.1016/j.ifacol.2019.09.174

Marklund, S 2017, 'The comparison of automatic and manual loading in an underground mining environment', viewed 16 January 2021, <http://urn.kb.se/resolve?urn=urn:nbn:se:ltu:diva-64900>

Memarzadeh, M, Golparvar-Fard, M & Niebles, JC 2013, 'Automated 2D detection of construction equipment and workers from site video streams using histograms of oriented gradients and colors', *Automation in Construction*, vol. 32, pp. 24–37. https://doi.org/10.1016/j.autcon.2012.12.002

Minerals Council South Africa (MCSA) 2020, *Facts and figures 2019*, viewed 16 January 2021, <https://www.mineralscouncil.org.za/>

Mining Review Africa 2019a, *Embracing technology with a methodical approach*, viewed 16 January 2021, <https://www.miningreview.com/gold/embracing-technology-with-a-methodical-adoption-approach/>

Mining Review Africa 2019b, *Technology key to the future of South Africa*, viewed 16 January 2021, <https://www.miningreview.com/gold/technology-key-to-the-future-of-the-mining-sector-in-south-africa/>

Mining Review Africa 2020, *South African mine fatalities at a record low*, viewed 10 January 2021, <https://www.miningreview.com/health-and-safety/south-africa-mining-fataliti/#:~:text=South%20African%20Mine%20fatalities%20at%20a%20record%20low&text=There%20was%20also%20a%202,improvements%20in%20disease%20incidence%20rates>

Mining Technology 2018, 'Mining vehicles ride times', viewed 10 January 2021, <https://www.mining-technology.com/features/mining-vehicles-ride-time/>

Molaei, F, Rahimi, E, Siavoshi, H, Setareh, GA & Victor, T 2020, 'A comprehensive review on internet of things (IoT) and its implications in the mining industry', *American Journal of Engineering and Applied Sciences*, vol. 13, pp. 499–515. https://doi.org/10.3844/ajeassp.2020.499.515

Moore, P 2019, *ABB outlines five levels in its vision of the autonomous mine of the future, international mining*, viewed 16 January 2021, <https://im-mining.com/2019/03/21/abb-outlines-five-levels-vision-autonomous-mine-future/>

Moore, P 2020, *Telia to make Boliden's Aitik open pit copper mine 5G-ready with Ericsson technology*, viewed 14 January 2021, <https://im-mining.com/2020/11/12/telia-make-bolidens-aitik-open-pit-copper-mine-5g-ready-ericsson-technology/>

Moroe, NF 2018, 'Occupational noise-induced hearing loss in South African large scale mines: From policy formulation to implementation and monitoring', Doctoral dissertation, University of the Witwatersrand. https://wiredspace.wits.ac.za/bitstream/handle/10539/27177/FINAL SUBMISSION23 Oct 2018.pdf?sequence=2&isAllowed=y

Moroe, N, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise–induced hearing loss in the mining sector in Africa: A systematic review – 1994 to 2016', *Noise & Vibration Worldwide*, vol. 49, no. 5, pp. 181–190. https://doi.org/10.1177/0957456518781860

Moroe, N, Khoza-Shangase, K, Madahana, M & Nyandoro, O 2019, 'A proposed preliminary model for monitoring hearing conservation programmes in the mining sector in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 119, no. 7, pp. 671–679. https://doi.org/10.17159/2411-9717/18/016/2019

Moroe, N, Khoza-Shangase, K, Madahana, M & Nyandoro, O 2020, 'Feedback-based noise management matrix in action', *South African Journal of Communication Disorders*, vol. 67, no. 2, pp. 1–9. https://doi.org/10.4102/sajcd.v67i2.678

Moroe, NF 2020, 'Occupational noise-induced hearing loss in South African large-scale mines: Exploring hearing conservation programmes as complex interventions embedded in a realist approach', *International Journal of Occupational Safety and Ergonomics*, vol. 26, no. 4, pp. 753–761. https://doi.org/10.1080/10803548.2018.1498183

Moroe, NF & Khoza-Shangase, K 2018, 'Management of occupational noise induced hearing loss in the mining sector in South Africa: Where are the audiologists?', *Journal of Occupational Health*, vol. 60, no. 5, pp. 376–382. https://doi.org/10.1539/joh.2018-0020-OA

Morton, J 2020, 'Machines that help reduce dilution', *Engineering and Mining Journal*, vol. 221, no. 8, pp. 28–33.

Moyo, D, Zungu, M, Kgalamono, S & Mwila, CD 2015, 'Review of occupational health and safety organization in expanding economies: The case of Southern Africa', *Annals of Global Health*, vol. 81, no. 4, pp. 495–502. https://doi.org/https://doi.org/10.1016/j.aogh.2015.07.002

Musiba, Z 2015, 'The prevalence of noise-induced hearing loss among Tanzanian miners', *Occupational Medicine (Oxford, England)*, vol. 65, no. 5, pp. 386–390. https://doi.org/10.1093/occmed/kqv046

Nair, DC 2014, 'Noise-induced hearing loss', *InnovAiT*, vol. 7, no. 4, pp. 204–208. https://doi.org/10.1177/1755738013518903

Narendran, TV & Weinelt, B 2017, *Digital transformation initiative mining and metals industry*, World Economic Forum, viewed 16 January 2021, <https://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/wef-dti-mining-and-metals-white-paper.pdf>

National Institute for Occupational Safety and Health (NIOSH) 1996, *National occupational research agenda*, DHHS Publication, viewed 15 July 2020, <https://www.cdc.gov/niosh/docs/96-115/default.html>

National Institute for Occupational Safety and Health (NIOSH) 2016, *Hierarchy of controls*, viewed 14 January 2021, <https://www.cdc.gov/niosh/topics/hierarchy/default.html>

Nebot, EM 2007, 'Surface mining: Main research issues for autonomous operations', in *Robotics research*, Springer, Berlin, pp. 268–280.

Nelson, DI, Nelson, RY, Concha-Barrientos, M & Fingerhut, M 2005, 'The global burden of occupational noise-induced hearing loss', *American Journal of Industrial Medicine*, vol. 48, no. 6, pp. 446–458. https://doi.org/10.1002/ajim.20223

Noone, G 2020, *What does the future hold for automation in the mining industry?*, NS Energy, viewed 10 January 2021, <https://www.nsenergybusiness.com/features/automation-mining-industry-future/#>

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', *Occupational Health Southern Africa*, vol. 21, no. 2, pp. 10–15.

NS Energy n.d., *Syma hold mine*, viewed 10 January 2021, <https://www.nsenergybusiness.com/projects/syama-gold-mine/>

O'Brien, TM, Harper, GS, Mnisi, M, Dias, B & Naidoo, D 2006, 'Project scope for low-noise drilling', *Research Agency: Council for Scientific and Industrial Research (CSIR), Final Project Report SIM* 5(05), 01, viewed 12 January 2021, <https://www.mhsc.org.za/sites/default/files/public/research_documents/SIM%20050501%20Reduction%20of%20noise%20level%20at%20source%20when%20making%20a%20mine%20blast%20hole%20Report.pdf>

Parreira, J 2013, 'An interactive simulation model to compare an autonomous Haulage truck system with a manually-operated system', Doctoral dissertation, University of British Columbia.

Pelders, JL, Nelson, G & Magweregwede, F 2019, *Shift cycles and fatigue in the South African mining industry*, viewed 12 January 2021, <http://researchspace.csir.co.za/dspace/handle/10204/11278>

Pendokhare, DG & Quazi, TZ 2012, 'Fuzzy logic based drilling control process', *International Journal of Scientific & Engineering Research*, vol. 5, no. 12, pp. 61–65.

Petty, J 2016, *Applying automation in the mining sector to environments in the public*, Australian Driverless Vehicle Initiative (ADVI), viewed 11 January 2021, <https://youtu.be/PF56HM2peSM>

Pretorius, JH & Mativenga, P 2019, *Enabling condition-based maintenance in precious metals processing*, viewed 10 January 2021, <https://ujcontent.uj.ac.za/vital/access/services/Download/uj:35396/SOURCE1>

Ramdoo, I 2019, *New tech, new deal: Technology impacts review*, Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development, viewed 10 January 2021, <https://www.iisd.org/system/files/publications/new-tech-new-deal-technology.pdf>

Roberts, JM, Duff, ES, Corke, PI, Sikka, P, Winstanley, GJ & Cunningham, J 2000, 'Autonomous control of underground mining vehicles using reactive navigation', in *Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No. 00CH37065)*, vol. 4, pp. 3790–3795, IEEE, viewed 14 July 2020, <https://ieeexplore.ieee.org/document/845322>

Rodríguez, P, Alonso, JB, Ferrer, MA & Carlos, T 2014, 'Review of automatic fault diagnosis systems using audio and vibration signals', *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 44, pp. 642–652.

Russell, MF & May, SP 1977, 'Machinery noise: the users' viewpoint', eds. SA Tobias, *Proceedings of the Seventeenth International Machine Tool Design and Research Conference*, Palgrave, London. https://link.springer.com/chapter/10.1007/978-1-349-81484-8_30

Sánchez, F & Hartlieb, P 2020, 'Innovation in the mining industry: Technological trends and a case study of the challenges of disruptive innovation', *Mining, Metallurgy & Exploration*, vol. 37, pp. 1385–1399. https://doi.org/10.1007/s42461-020-00262-1

Sekar, S, Lundin, K, Tucker, C, Figueiredo, J & Aguilar, J 2019, *Building resilience: A green growth framework for mobilizing mining investment*, World Bank Publications, viewed 10 January 2021, <https://documents1.worldbank.org/curated/en/689241556650241927/pdf/Building-Resilience-A-Green-Growth-Framework-for-Mobilizing-Mining-Investment.pdf>

Sensogut, C 2007, 'Occupational noise in mines and its control: A case study', *Polish Journal of Environmental Studies*, vol. 16, pp. 933–936.

Shi, X, Lever, PJ & Wang, FY 1996, 'Experimental robotic excavation with fuzzy logic and neural networks', in *Proceedings of IEEE International Conference on Robotics and Automation*, vol. 1, pp. 957–962. https://scienceon.kisti.re.kr/srch/selectPORSrchArticle.do?cn=NPAP00165175

Somua-Gyimah, G, Frimpong, S, Nyaaba, W & Gbadam, E 2019, 'A computer vision system for terrain recognition and object detection tasks in mining and construction environments', in *SME annual conference*, Denver, 24–27 February.

Stanton, DW 2003, 'Report of the commission of inquiry into safety and health in the mining industry', *The South African OHS Commissions*, vol. 1, no. 1, pp. 1–192. https://www.dmr.gov.za/Portals/0/Resource%20Center/Reports%20and%20Other%20Documents/2003_Leon%20Commission_Volume%201.pdf?ver=2018-03-13-020431-270

Sukkarieh, S, Nebot, EM & Durrant-Whyte, HF 1999, 'A high integrity IMU/GPS navigation loop for autonomous land vehicle applications', *IEEE Transactions on Robotics and Automation*, vol. 15, no. 3, pp. 572–578. https://doi.org/10.1109/70.768189

Thompson, D 1999, 'Modern drilling and blasting technology at the Minntac mine', *MINNBLAST*, vol. 99, pp. 79–96.

Wang, W & Siau, K 2019, 'Artificial intelligence, machine learning, automation, robotics, future of work and future of humanity: A review and research agenda', *Journal of Database Management*, vol. 30, no. 1, pp. 61–79. https://doi.org/10.4018/JDM.2019010104

Wei, ZHOU, Cai, QX & Chen, SZ 2007, ‘Study on dragline-bulldozer operation with variations in coal seam thickness’, *Journal of China University of Mining and Technology*, vol. 17, no. 4, pp. 464–466. https://doi.org/10.1016/S1006-1266(07)60126-6

Willingham, D & Marchant, R 2016, ‘Predictive maintenance using simulation and machine learning’, in *Proceedings of the 13th The Australasian Institute of Mining and Metallurgy Mill Operators’ Conference*, pp. 279–283, viewed 14 July 2020, <https://www.onemine.org/document/abstract.cfm?docid=234754>

Winstanley, G, Corke, PI & Roberts, J 1999, *Dragline automation implementation*, Australian Coal Association Research Program Project Report, (C5003), viewed 12 July 2020, <https://www.acarp.com.au/abstracts.aspx?repId=C5003>

Xu, Z, Yang, W, You, K, Li, W & Kim, YI 2017, ‘Vehicle autonomous localization in local area of coal mine tunnel based on vision sensors and ultrasonic sensors’, *PLoS One*, vol. 12, no. 1, a0171012. https://doi.org/10.1371/journal.pone.0171012

Chapter 8

Abdalla, S, Apramian, SS, Cantley, L & Cullen, MR 2017, *Occupation and risk for injuries*, viewed 18 February 2021, <https://www.ncbi.nlm.nih.gov/books/NBK525209/>

Abdallah, O, Ageeb, RA, Elkhalifa, WHI, Zolezzi, M, El-Awaisi, A, Diab, MI & Awaisu, A 2020, ‘Evaluating prescribing competencies covered in a Canadian-accredited undergraduate pharmacy program in Qatar: A curriculum mapping process’, *BMC Medical Education*, vol. 20, no. 1, pp. 1–8. https://doi.org/10.1186/s12909-020-02109-1

Ali, SA 2011, ‘Industrial noise levels and annoyance in Egypt’, *Applied Acoustics*, vol. 72, no. 4, pp. 221–225. https://doi.org/10.1016/j.apacoust.2010.11.001

Alli, BO 2008, *Fundamental principles of occupational health and safety*, 2nd edn., International Labour Office, viewed 10 April 2018, <https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms_093550.pdf>

Amedofu, GK 2007, ‘Effectiveness of hearing conservation program at a large surface gold mining company in Ghana’, *African Journal of Health Sciences*, vol. 14, no. 1, pp. 49–53. https://doi.org/10.4314/ajhs.v14i1.30846

Amedofu, GK & Fuente, A 2008, ‘Occupational hearing loss in develpoing countries’, in B McPherson & R Bbouillette (eds.), *Audiology in developing countries*, Nova Science Publishers, Inc, Hauppauge, New York, pp. 189–221.

Annan, JS, Addai, EK & Tulashie, SK 2015, ‘A call for action to improve occupational health and safety in Ghana and a critical look at the existing legal requirement and legislation’, *Safety and Health at Work*, vol. 6, no. 2, pp. 146–150. https://doi.org/10.1016/j.shaw.2014.12.002

Basson, A, Le Roux, P & Strydom, E 2009, *Essential labour law*, Labour Law Publications, Centurion.

Bolaji, BO, Olanipekun, MU, Adekunle, AA & Adeleke, AE 2018, ‘An analysis of noise and its environmental burden on the example of Nigerian manufacturing companies’, *Journal of Cleaner Production*, vol. 172, pp. 1800–1806. https://doi.org/10.1016/j.jclepro.2017.12.007

Bruce, RD 2007, *Engineering controls for reducing workplace noise*, National Academy of Engineering, vol. 37, no. 3, pp. 33–39. https://www.nae.edu/7687/EngineeringControlsforReducingWorkplaceNoise

Chadambuka, A, Mususa, F & Muteti, S 2013, ‘Prevalence of noise induced hearing loss among employees at a mining industry in Zimbabwe’, *African Health Science*, vol. 13, no. 4, pp. 899–906. https://doi.org/10.4314/ahs.v13i4.6

Chau, N, Dehaene, D, Benamghar, L, Bourgkard, E, Mur, JM, Touron, C & Wild, P 2014, ‘Roles of age, length of service and job in work-related injury: a prospective study of 63,620 person-years in female workers’, *American Journal of Industrial Medicine*, vol. 57, no. 2, pp. 172–183. https://doi.org/10.1002/ajim.22259

Chirwa, I, Mlatho, JS, Kamunda, C & Mikeka, C 2019, ‘Assessment of noise levels in heavy and light industries in Blantyre City, Malawi’, *Malawi Journal of Science and Technology*, vol. 11, no. 1, pp. 73–92.

Edwards, AL & Kritzinger, D 2012, ‘Noise-induced hearing loss milestones: Past and future’, *The Journal of The Southern African Institute of Mining and Metallurgy*, vol. 112, pp. 865–869. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532012001000006&lng=en&nrm=iso

Fuente, A & Hickson, L 2011, ‘Noise-induced hearing loss in Asia’, *International Journal of Audiology*, vol. 50, suppl. 1, pp. 3–10. https://doi.org/10.3109/14992027.2010.540584

Government of Alberta 2011, *Handbook of occupational hazards and controls for public health workers*, Government of Alberta, viewed 18 February 2021, <https://open.alberta.ca/dataset/ad88cc78-bcc2-41ae-80c5-cf8fbc7ba0e0/resource/9f141d29-d49b-48fc-a521-ef4b94d94e8a/download/ohs-wsa-handbook-public-health-workers.pdf>

Guild, R, Ehrlich, RI, Johnston, JR & Ross, MH 2001, *A handbook on occupational health practice in the South African Mining Industry*, The Safety in Mines Research Advisory Committee (SIMRAC), viewed 10 January 2018, <https://www.mhsc.org.za/sites/default/files/public/publications/OH%20Handbook.pdf>

Gunasekaran, SS, Mostafa, SA, Ahmad, MS & Tang, A 2017, ‘Cross-fertilization of ideas in Collective Intelligence Model (CIM)’, in *2nd International Symposium on Agent, Multi-Agent Systems and Robotics (ISAMSR)*, 23–24 August, 2016, Bangi.

Gyamfi, CKR, Amankwaa, I, Sekyere, FO & Boateng, D 2016, ‘Noise exposure and hearing capabilities of quarry workers in Ghana: A cross-sectional study’, *Journal of Environmental and Public Health*, vol. 2016, a7054276. https://doi.org/10.1155/2016/7054276

International Labour Organization 2014, *Safety and health at work: A vision for sustainable prevention*, viewed 19 February 2021, <https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_301214.pdf>

International Social Security Association 2014, *Towards a global culture of prevention: Working conditions have a major and direct impact on the health and well-being of workers*, Geneva, viewed 18 February 2021, <https://ww1.issa.int/sites/default/files/documents/publications/2-issa-prevention-2016-29824.pdf>

Kheni, NA, Dainty, ARJ & Gibb, A 2008, ‘Health and safety management in developing countries: A study of construction SMEs in Ghana’, *Construction Management and Economics*, vol. 26, no. 11, pp. 1159–1169. https://doi.org/10.1080/01446190802459916

Khoza-Shangase, K 2020a, ‘Burden of disease: a scoping review of HIV/AIDS and TB in occupational noise-induced hearing loss’, *South African Journal of Communication Disorders*, vol. 67, no. 2, pp. 1–9. https://doi.org/10.4102/sajcd.v67i2.669

Khoza-Shangase, K 2020b, ‘Hearing function of gold miners with and without a history of tuberculosis treatment: A retrospective data review’, *Brazilian Journal of Otorhinolaryngology*, vol. 86, no. 3, pp. 294–299. https://doi.org/10.1016/j.bjorl.2018.12.003

Khoza-Shangase, K 2022, ‘Occupational noise-induced hearing loss and preventive audiology: Using contemporary evidence to achieve zero ear harm in South African mines’, ed. K Khoza-Shangase, *Preventive audiology: An African perspective*, AOSIS Books, AOSIS Publishing (Pty) Ltd, Cape Town, pp. 235–251. https://doi.org/10.4102/aosis.2022.BK209.12

Khoza-Shangase, K, Moroe, N & Edwards, A 2020, ‘Occupational hearing loss in Africa: An interdisciplinary view of the current status’, *South African Journal of Communications Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Kitcher, ED, Ocansey, G, Abaidoo, B & Atule, A 2014, ‘Occupational hearing loss of market mill workers in the city of Accra, Ghana’, *Noise and Health*, vol. 16, no. 70, pp. 183–188. https://doi.org/10.4103/1463-1741.134919

LaDou, J 2003, ‘International occupational health’, *International Journal of Hygiene and Environmental Health*, vol. 206, no. 4, pp. 303–313. https://doi.org/10.1078/1438-4639-00226

Leigh, JP & Marcin, JP 2012, 'Workers' compensation benefits and shifting costs for occupational injury and illness', *Journal of Occupational and Environmental Medicine*, vol. 54, no. 4, pp. 445–450. https://doi.org/10.1097/JOM.0b013e3182451e54

Liu, S, Nkrumah, ENK, Akoto, LS, Gyabeng, E & Nkrumah, E 2020, 'The state of occupational health and safety management frameworks (OHSMF) and occupational injuries and accidents in the Ghanaian oil and gas industry: Assessing the mediating role of safety knowledge', *BioMed Research International*, vol. 2020, a6354895. https://doi.org/10.1155/2020/6354895

Manning, WG & Pillay, M 2020, 'A critical analysis of the current South African occupational health law and hearing loss', *South African Journal of Communication Disorders*, vol. 67, no. 2, a694. https://doi.org/10.4102/sajcd.v67i2.694

Meerding, WJ, Ijzelenberg, W, Koopmanschap, MA, Severens, JL & Burdorf, A 2005, 'Health problems lead to considerable productivity loss at work among workers with high physical load jobs', *Journal of Clinical Epidemiology*, vol. 58, no. 5, pp. 517–523. https://doi.org/10.1016/j.jclinepi.2004.06.016

Moroe, N, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise-induced hearing loss in the mining sector in Africa: A systematic review – 1994 to 2016', *Noise & Vibration Worldwide*, vol. 49, no. 5, pp. 181–190. https://doi.org/10.1177/0957456518781860

Moroe, NF 2020, 'Occupational noise-induced hearing loss in South African large-scale mines: Exploring hearing conservation programmes as complex interventions embedded in a realist approach', *International Journal of Occupational Safety and Ergonomics*, vol. 26, no. 4, pp. 753–761. https://doi.org/10.1080/10803548.2018.1498183

Moyo, D, Zungu, M, Kgalamono, S & Mwila, CD 2015, 'Review of occupational health and safety organization in expanding economies: The case of Southern Africa', *Annals of Global Health*, vol. 81, no. 4, pp. 495–502. https://doi.org/10.1016/j.aogh.2015.07.002

Mrema, EJ, Ngowi, AV & Mamuya, SHD 2015, 'Status of occupational health and safety and related challenges in expanding economy of Tanzania', *Annals of Global Health*, vol. 81, no. 4, pp. 538–547. https://doi.org/10.1016/j.aogh.2015.08.021

Musiba, Z 2015, 'The prevalence of noise-induced hearing loss among Tanzanian miners', *Occupational Medicine*, vol. 65, no. 5, pp. 386–390. https://doi.org/10.1093/occmed/kqv046

National Institute for Occupational Safety and Health (NIOSH) 2016, *Hierarchy of controls*, viewed 18 February 2018, <https://www.cdc.gov/niosh/topics/hierarchy/>

Ncube, F & Kanda, A 2018, 'Current status and the future of occupational safety and health legislation in low-and-middle-income countries', *Safety and Health at Work*, vol. 9, no. 4, pp. 365–371. https://doi.org/10.1016/j.shaw.2018.01.007

Parsons, KC 2000, 'Environmental ergonomics: A review of principles, methods and models', *Applied Ergonomics*, vol. 31, no. 6, pp. 581–594. https://doi.org/10.1016/S0003-6870(00)00044-2

Posel, D, Fairburn, JA & Lund, F 2006, 'Labour migration and households: A reconsideration of the effects of the social pension on labour supply in South Africa', *Economic Modelling*, vol. 23, no. 5, pp. 836–853. https://doi.org/10.1016/j.econmod.2005.10.010

Puplampu, BB 2012, 'Key issues on occupational health and safety practices in Ghana: A review', *International Journal of Business and Social Science*, vol. 3, no. 19, pp. 151–156.

Rupprecht, SM 2017, *Bench mining utilizing manual labour and mechanized equipment: A proposed mining method for artisanal small-scale mining in Central Africa*, The Southern African Institute of Mining and Metallurgy, vol. 117, no. 1, pp. 25–31. https://doi.org/10.17159/2411-9717/2017/v117n1a5

Schenker, MB 2010, 'A global perspective of migration and occupational health', *American Journal of Industrial Medicine*, vol. 53, no. 4, pp. 329–337. https://doi.org/10.1002/ajim.20834

Schmidt, CW 2008, 'Linking TB and the environment: An overlooked mitigation strategy', *Environmental Health Perspectives*, vol. 116, no. 11, pp. 478–485. https://doi.org/10.1289/ehp.116-a478

Simons, HJ 1960, 'Death in South African mines', *Africa South*, vol. 5, no. 4, pp. 41–55, viewed 18 February 2021, <http://www.sahistory.org.za/sites/default/files/DC/asjul61.8/asjul61.8.pdf>

Stanton, DW 2003, *Report of the commission of inquiry into safety and health in the mining industry*, The South African OHS Commissions, Pretoria, pp. 1–192.

Stewart, JM & Malatji, SM 2018, ‘Development of the MOSH leading practice adoption system – a science-based system for managing behaviour change’, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 118, no. 3, pp. 259–277. https://doi.org/10.17159/2411-9717/2018/v118n3a9

Stuckler, D, Steele, S, Lurie, M & Basu, S 2013, ‘“Dying for gold”: The effects of mineral mining on HIV, tuberculosis, silicosis and occupational diseases in southern Africa’, *International Journal of Health Services: Planning, Administration, Evaluation*, vol. 43, no. 4, pp. 639–649. https://doi.org/10.2190/HS.43.4.c

Suter, AH 2012, ‘Engineering controls for occupational noise exposure: The best way to save hearing’, *Sound and Vibrations*, vol. 45, pp. 21–31.

Suter, AH n.d., *The nature and effects of noise*, 4th edn., Canadian Centre for Occupational Health and Safety (CCOHS), Hamilton.

Takala, J, Hämäläinen, P, Saarela, KL, Yun, LY, Manickam, K, Jin, TW, Heng, P, Tjong, C, Kheng, LG, Lim, S & Lin, GS 2014, ‘Global estimates of the burden of injury and illness at work in 2012’, *Journal of Occupational and Environmental Hygiene*, vol. 11, no. 5, pp. 326–337. https://doi.org/10.1080/15459624.2013.863131

Teke, Z 2017, ‘Probe into struggles of ex-miners’, *Sunday Tribune*, viewed 16 February 2021, <https://web.archive.org/web/20211125140639/https://www.iol.co.za/sunday-tribune/news/probe-into-struggles-of-ex-miners-11515422>

Themann, CL & Masterson, EL 2019, ‘Occupational noise exposure: A review of its effects, epidemiology, and impact with recommendations for reducing its burden’, *The Journal of the Acoustical Society of America*, vol. 146, no. 5, pp. 3879–3905. https://doi.org/10.1121/1.5134465

Tshoose, C 2014, ‘Placing the right to occupational health and safety within a human rights framework: Trends and challenges for South Africa’, *The Comparative and International Law Journal of Southern Africa*, vol. 47, no. 2, pp. 276–296. http://www.jstor.org/stable/24585872

Wang, X, Orelaja, OA, Ibrahim, DS & Ogbonna, SM 2020, ‘Evaluation of noise risk level and its consequences on technical operators of tobacco processing equipment in a cigarette producing company in Nigeria’, *Scientific African*, vol. 8, a00344. https://doi.org/10.1016/j.sciaf.2020.e00344

Zungu, LI 2012, ‘Occupational health and safety challenges reported by women in selected South African gold and platinum mines’, *Journal of Occupational Health Southern Africa*, vol. 18, no. 5, pp. 6–13.

Chapter 9

Adams, S, Ehrlich, R, Quail, Z, Jeebhay, MF & Ismail, N 2012, ‘Occupational health challenges facing the department of health: Protecting employees against tuberculosis and caring for former mineworkers with occupational health disease’, *South African Health Review*, vol. 2012, no. 13, pp. 67–82.

Agrawal, Y, Platz, EA & Niparko, JK 2009, ‘Risk factors for hearing loss in US adults: Data from the national health and nutrition examination survey, 1999 to 2002’, *Otology & Neurotology*, vol. 30, no. 2, pp. 139–145. https://doi.org/10.1097/MAO.0b013e318192483c

Amiri, F, Zamanian, Z, Mani, A & Hasanzadeh, J 2015, ‘Effects of combined exposure to noise, heat and lighting on cognitive performance’, *Iran Occupational Health*, vol. 12, no. 5, pp. 10–20.

Amjad-Sardrudi, H, Dormohammadi, A, Golmohammadi, R & Poorolajal, J 2012, ‘Effect of noise exposure on occupational injuries: a cross-sectional study’, *Journal of Research in Health Sciences*, vol. 12, pp. 101–104.

AngloGold Ashanti 2012, *Country fact sheet South Africa*, viewed 21 February 2021, <http://www.aga-reports.com/12/>

Barwise, K, Lind, A, Bennett, R & Martins, E 2013, 'Intensifying action to address HIV and tuberculosis in Mozambique's cross-border mining sector', *International Journal of Health Services*, vol. 43, no. 4, pp. 699–719. https://doi.org/10.2190/HS.43.4.g

Bowens, A 2018a, *Evidence updates on risk factors for occupational noise-induced hearing loss (ONIHL) update 3: Genetic factors*, viewed 18 February 2021, <https://www.acc.co.nz/assets/research/63e6836c44/ONIHL-evidence-genetics.pdf>

Bowens, A 2018b, *Evidence updates on risk factors for occupational noise-induced hearing loss (ONIHL) update 1: Exposure to solvents with or without noise*, viewed 21 February 2021, <https://www.acc.co.nz/assets/research/23160770fb/ONIHL-evidence-solvents.pdf>

Bradshaw, D, Nannan, NN, Pillay-van Wyk, V, Laubscher, R, Groenewald, P & Dorrington, RE 2019, 'Burden of disease in South Africa: Protracted transitions driven by social pathologies', *South African Medical Journal*, vol. 109, no. 11b, pp. 69–76. https://doi.org/10.7196/SAMJ.2019.v109i11b.14273

Brits, J, Strauss, S, Eloff, Z, Becker, PJ & Swanepoel, DW 2012, 'Hearing profile of gold miners with and without tuberculosis', *Occupational and Environmental Medicine*, vol. 69, no. 4, pp. 243–249. https://doi.org/10.1136/oemed-2011-100106

Cantley, LF, Galusha, D, Cullen, MR, Dixon-Ernst, C, Rabinowitz, PM & Neitzel, RL 2015, 'Association between ambient noise exposure, hearing acuity, and risk of acute occupational injury', *Scandinavian Journal of Work, Environment & Health*, vol. 41, no. 1, pp. 75–83. https://doi.org/10.5271/sjweh.3450

Chaisson, RE & Martinson, NA 2008, 'Tuberculosis in Africa: Combating an HIV-driven crisis', *New England Journal of Medicine*, vol. 358, no. 11, pp. 1089–1092. https://doi.org/10.1056/NEJMp0800809

Chen, KH, Su, SB & Chen, KT 2020, 'An overview of occupational noise-induced hearing loss among workers: Epidemiology, pathogenesis, and preventive measures', *Environmental Health and Preventive Medicine*, vol. 25, no. 1, pp. 1–10. https://doi.org/10.1186/s12199-020-00906-0

Concha-Barrientos, M, Campbell-Lendrum, D & Steenland, K 2004, *Occupational noise: Assessing the burden of disease from work-related hearing impairment at national and local levels*, Environmental Burden of Disease Series, No. 9, viewed 21 February 2021, <https://apps.who.int/iris/handle/10665/43001>

Coovadia, H, Jewkes, R, Barron, P, Sanders, D & McIntyre, D 2009, 'The health and health system of South Africa: Historical roots of current public health challenges', *Lancet (London, England)*, vol. 374, no. 9692, pp. 817–834. https://doi.org/10.1016/S0140-6736(09)60951-X

Edwards, AL 2009, '85 dBA: is it protective enough to prevent hearing loss in South African miners?', *paper presented at The Southern African Institute of Mining and Metallurgy, Hard Rock Safe Safety Conference 2009*, viewed 21 February 2021, <https://researchspace.csir.co.za/dspace/handle/10204/3674>

Eisler, R 2003, 'Health risks of gold miners: A synoptic review', *Environmental Geochemistry and Health*, vol. 25, no. 3, pp. 325–345.

Elgstrand, K & Vingård, E 2013, *Occupational safety and health in mining: Anthology on the situation in 16 mining countries*, Occupational and Environmental Medicine, University of Gothenburg, viewed 21 February 2021, <https://gupea.ub.gu.se/bitstream/2077/32882/1/gupea_2077_32882_1.pdf>

Fagan, J & Jacobs, M 2009, 'Survey of ENT services in Africa: Need for a comprehensive intervention', *Global Health Action*, vol. 2, no. 1, a1932. https://doi.org/10.3402/gha.v2i0.1932

Fransen, E, Topsakal, V, Hendrickx, JJ, Van Laer, L, Huyghe, JR, Van Eyken, E et al. 2008, 'Occupational noise, smoking, and a high body mass index are risk factors for age-related hearing impairment and moderate alcohol consumption is protective: A European population-based multicenter study', *Journal of the Association for Research in Otolaryngology*, vol. 9, no. 3, pp. 264–276. https://doi.org/10.1007/s10162-008-0123-1

Fuortes, LJ, Tang, S, Pomrehn, P & Anderson, C 1995, 'Prospective evaluation of associations between hearing sensitivity and selected cardiovascular risk factors', *American Journal of Industrial Medicine*, vol. 28, no. 2, pp. 275–280. https://doi.org/10.1002/ajim.4700280211

Gebru, AA, Birhanu, T, Wendimu, E, Ayalew, AF, Mulat, S, Abasimel, HZ, Kazemi, A, Tadesse, BA, Gebru, BA, Deriba, BS, Zeleke, NS, Girma, AG, Munkhbat, B, Yusuf, QK, Luke, AO & Hailu, D 2021, 'Global burden of COVID-19: Situational analysis and review', *Human Antibodies*, vol. 29, no. 2, pp. 139–148. https://doi.org/10.3233/HAB-200420

Girard, SA, Leroux, T, Courteau, M, Picard, M, Turcotte, F & Richer, O 2015, 'Occupational noise exposure and noise-induced hearing loss are associated with work-related injuries leading to admission to hospital', *Injury Prevention*, vol. 21, no. e1, pp. 88–92. https://doi.org/10.1136/injuryprev-2013-040828

Golmohammadi, R & Darvishi, E 2019, 'The combined effects of occupational exposure to noise and other risk factors: A systematic review', *Noise & Health*, vol. 21, no. 101, pp. 125–141. https://doi.org/10.4103/nah.nah_4_18

Haagsma, JA, Graetz, N, Bolliger, I, Naghavi, M, Higashi, H, Mullany, EC et al. 2016, 'The global burden of injury: Incidence, mortality, disability-adjusted life years and time trends from the Global Burden of Disease study 2013', *Injury Prevention*, vol. 22, no. 1, pp. 3–18. https://doi.org/10.1136/injuryprev-2015-041616

Hessel, F 2008, 'Burden of disease', in W Kirch (ed.), *Encyclopedia of public health*, Springer, Dordrecht, pp. 57–96. https://doi.org/10.1007/978-1-4020-5614-7_297

Hofman, K & Madhi, S 2020, 'The unanticipated costs of COVID-19 to South Africa's quadruple disease burden', *South African Medical Journal*, vol. 110, no. 8, pp. 689–699. https://doi.org/10.7196/SAMJ.2020.v110i8.15125

Institute for Health Metrics and Evaluation (IHME) 2018, *Findings from the global burden of disease study 2017*, viewed 20 February 2021, <http://www.healthdata.org/sites/default/files/files/policy_report/2019/GBD_2017_Booklet.pdf>

Ishii, EK, Talbott, EO, Findlay, RC, D'Antonio, JA & Kuller, LH 1992, 'Is NIDDM a risk factor for noise-induced hearing loss in an occupationally noise exposed cohort?', *The Science of the Total Environment*, vol. 127, no. 1–2, pp. 155–165. https://doi.org/10.1016/0048-9697(92)90474-7

Jewell, BL, Mudimu, E, Stover, J, Ten Brink, D, Phillips, AN, Smith, JA, Martin-Hughes, R, Teng, Y, Glaubius, R, Mahiane, SG, Bansi-Matharu, L, Taramusi, I, Chagoma, N, Morrison, M, Doherty, M, Marsh, K, Bershteyn, A, Hallett, TB, Kelly, SL & HIV Modelling Consortium 2020, 'Potential effects of disruption to HIV programmes in sub-Saharan Africa caused by COVID-19: Results from multiple mathematical models', *The Lancet HIV*, vol. 7, no. 9, pp. 629–640. https://doi.org/10.1016/S2352-3018(20)30211-3

Kanji, A & Khoza-Shangase, K 2019, 'Early detection of hearing impairment in high-risk neonates: Let's talk about the high-risk registry in the South African context', *South African Journal of Child Health*, vol. 13, no. 2, pp. 53–55.

Khoza-Shangase, K 2010a, 'HIV/AIDS and auditory function in adults: The need for intensified research in the developing world', *African Journal of AIDS Research*, vol. 9, no. 1, pp. 1–9. https://doi.org/10.2989/16085906.2010.484531

Khoza-Shangase, K 2010b, 'Is there a need for ototoxicity monitoring in patients with HIV/AIDS?', *African Journal of Pharmacy & Pharmacology*, vol. 4, pp. 574–579. https://academicjournals.org/article/article1380787409_Katijah.pdf

Khoza-Shangase, K 2011, 'Highly active antiretroviral therapy: Does it sound toxic?', *Journal of Pharmacy & Bioallied Sciences*, vol. 3, no. 1, pp. 142–153. https://doi.org/10.4103/0975-7406.76494

Khoza-Shangase, K 2017, 'Risk versus benefit: Who assesses this in the management of patients on ototoxic drugs?', *Journal of Pharmacy & Bioallied Sciences*, vol. 9, no. 3, pp. 171–177. https://doi.org/10.4103/jpbs.JPBS_17_17

Khoza-Shangase, K 2019, 'Pharmaco-audiology vigilance in the treatment of patients with HIV/AIDS: Ototoxicity monitoring protocol recommendation', *Infectious Disorders – Drug Targets*, vol. 19, no. 1, pp. 1–9. https://doi.org/10.2174/1871526518666181016102102

Khoza-Shangase, K 2020a, 'Burden of disease: A scoping review of HIV/AIDS and TB in occupational noise-induced hearing loss', *South African Journal of Communication Disorders*, vol. 67, no. 2, a669. https://doi.org/10.4102/sajcd.v67i2.669

Khoza-Shangase, K 2020b, ‘Hearing function of gold miners with and without a history of tuberculosis treatment: A retrospective data review’, *Brazilian Journal of Otorhinolaryngology*, vol. 86, no. 3, pp. 294–299. https://doi.org/10.1016/j.bjorl.2018.12.003

Khoza-Shangase, K 2021a, ‘HIV/AIDS and the burden of disease in early hearing detection and intervention’, eds. K Khoza-Shangase & A Kanji, *Early detection and intervention in audiology: an African perspective*, Wits University Press, Johannesburg, p. 219.

Khoza-Shangase, K 2021b, ‘Confronting realities to early hearing detection in South Africa’, eds. K Khoza-Shangase & A. Kanji, *Early detection and intervention in audiology: an African perspective*, Wits University Press, Johannesburg, pp. 66–88.

Khoza-Shangase, K 2022, ‘Are masks used during COVID-19 masking hearing impairment caused by the pandemic? A scoping review of cochleovestibular findings for clinical care planning in South Africa’, *South African Journal of Communication Disorders*, vol. 69, no. 2*.*

Khoza-Shangase, K, Moroe, N, Neille, J & Edwards, A 2022, ‘The impact of COVID-19 in speech-language and hearing professions in low-and-middle-income countries: Challenges and opportunities explored’, *South African Journal of Communication Disorders*, vol. 69, no. 2, a937. https://doi.org/10.4102/sajcd.v69i2.937

Khoza-Shangase, K & Moroe, NF 2020, ‘Risk versus benefit: Should not audiologists assess this in the context of occupational noise-induced hearing loss in the mining industry?’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a671. https://doi.org/10.4102/sajcd.v67i2.671

Khoza-Shangase, K & Prodromos, M 2021, ‘Impact of drug-resistant tuberculosis treatment on hearing function in South African adults: Bed aquiline versus kanamycin’, *South African Journal of Communication Disorders*, vol. 68, no. 1, a784. https://doi.org/10.4102/sajcd.v68i1.784

Kistnasamy, B, Yassi, A, Yu, J, Spiegel, SJ, Fourie, A, Barker, S & Spiegel, JM 2018, ‘Tackling injustices of occupational lung disease acquired in South African mines: Recent developments and ongoing challenges’, *Globalization and Health*, vol. 14, no. 1, p. 60. https://doi.org/10.1186/s12992-018-0376-3

Landier, W 2016, ‘Ototoxicity and cancer therapy’, *Cancer*, vol. 122, no. 11, pp. 1647–1658. https://doi.org/10.1002/cncr.29779

Lie, A, Skogstad, M, Johannessen, HA, Tynes, T, Mehlum, IS, Nordby, KC, Engdahl, B & Tambs, K 2016, ‘Occupational noise exposure and hearing: A systematic review’, *International Archives of Occupational and Environmental Health*, vol. 89, no. 3, p. 351. https://doi.org/10.1007/s00420-015-1083-5

Lonsbury-Martin, BL & Martin, GK 2001, ‘Evoked otoacoustic emissions as objective screeners for ototoxicity’, *Seminars in Hearing*, vol. 22, no. 4, pp. 377–392. https://doi.org/10.1055/s-2001-19111

Mbazima, N 2020, ‘Reviving a declining mining industry’, *Viewpoints*, viewed 18 February 2021, <https://www.africaportal.org/publications/reviving-declining-mining-industry/>

Minerals Council of South Africa (MCSA) 2020, *Tuberculosis in the South African Mining Industry: Fact Sheet*, viewed 18 February 2021, <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjy5IWYp6_uAhV5ahUIHQtNDksQFjAAegQIARAC&url=https%3A%2F%2Fwww.mineralscouncil.org.za%2Findustry-news%2Fpublications%2Ffact-sheets%2Fsend%2F3-fact-sheets%2F749-tuberculosis-in-south-africa&usg=AOvVaw3pBN1kh6TBoA6SQWbtZKwC>

Mining Review Africa 2020, *South African mine fatalities at a record low*, viewed 18 February 2021, <https://www.miningreview.com/health-and-safety/south-africa-mining-fataliti/#:~:text=South%20African%20Mine%20fatalities%20at%20a%20record%20low&text=There%20was%20also%20a%202,improvements%20in%20disease%20incidence%20rates>

Mulwafu, W, Ensink, R, Kuper, H & Fagan, J 2017, ‘Survey of ENT services in sub-Saharan Africa: Little progress between 2009 and 2015’, *Global Health Action*, vol. 10, no. 1, a1289736. https://doi.org/10.1080/16549716.2017.1289736

Norman, R, Matzopoulos, R, Groenewald, P & Bradshaw, D 2007, ‘The high burden of injuries in South Africa’, *Bulletin of the World Health Organization*, vol. 85, pp. 695–702. https://doi.org/10.2471/BLT.06.037184

Ntlhakana, L, Khoza-Shangase, K & Nelson, G 2020, 'Occupational noise-induced hearing loss in platinum miners: What do the data tell us?', *Occupational Health Southern Africa*, vol. 26, no. 1, pp. 8–14. https://doi.org/10.17159/2411-9717/1318/2021

Pillay, M, Tiwari, R, Kathard, H & Chikte, U 2020, 'Sustainable workforce: South African audiologists and speech therapists', *Human Resources for Health*, vol. 18, no. 1, pp. 1–13. https://doi.org/10.1186/s12960-020-00488-6

Pillay-van Wyk, V, Msemburi, W, Laubscher, R, Dorrington, RE, Groenewald, P, Glass, T, Nojilana, B, Joubert, JD, Matzopoulos, R, Prinsloo, M, Nannan, N, Gwebushe, N, Vos, T, Somdyala, N, Sithole, N, Neethling, I, Nicol, E, Rossouw, A & Bradshaw, D 2016, 'Mortality trends and differentials in South Africa from 1997 to 2012: Second national burden of disease study', *The Lancet Global Health*, vol. 4, pp. 642–653. https://doi.org/10.1016/S2214-109X(16)30113-9

Prinsloo, M, Kotzenberg, C & Seedat, M 2007, *A profile of fatal injuries in South Africa: 7th annual report of the national injury mortality surveillance system 2005*, Medical Research Council/UNISA Crime, Violence and Injury Lead Programme, Cape Town.

Ratsela, K 2018, *A silent killer: Why South Africa's health could crumble under pressure from non-communicable diseases*, viewed 17 February 2021, <https://www.samrc.ac.za/media-release/silent-killer-why-south-africa%E2%80%99s-health-could-crumble-under-pressure-non-communicable#:~:text=The%20four%20major%20NCDs%20share,NCD%20epidemic%20in%20South%20Africa>

Reddy, M & Swanepoel, B 2006, 'Cutting the cost of HIV', *Harvard Business Review*, vol. 84, no. 9, pp. 21–22.

Roberton, T, Carter, ED, Chou, VB, Stegmuller, AR, Jackson, BD, Tam, Y, Sawadogo-Lewis, T & Walker, N 2020, 'Early estimates of the indirect effects of the COVID-19 pandemic on maternal and child mortality in low-income and middle-income countries: A modelling study', *Lancet Global Health*, vol. 8, no. 7, pp. 901–908. https://doi.org/10.1016/S2214-109X(20)30229-1

Rohde, J, Cousens, S, Chopra, M, Tangcharoensathien, V, Black, R, Bhutta, ZA & Lawn, JE 2008, '30 years after Alma-Ata: Has primary health care worked in countries?', *The Lancet*, vol. 372, no. 9642, pp. 950–961. https://doi.org/10.1016/S0140-6736(08)61405-1

Sebothoma, B & Khoza-Shangase, K 2022, 'Middle ear status – structure, function, and pathology: A scoping review on middle ear status of COVID-19 positive patients', *South African Journal of Communication Disorders*, vol. 69, no. 2, a910. https://doi.org/10.4102/sajcd.v69i2.910

Shange, N 2020, *Almost 11,000 HIV-positive patients in Gauteng have skipped ARV collection during lockdown*, Sowetanlive, viewed 17 February 2021, <https://www.sowetanlive.co.za/news/south-africa/2020-05-19-almost-11000-hiv-positive-patients-in-gauteng-have-skipped-arv-collection-during-lockdown/>

Steyn, D 2020, 'COVID-19: SA's TB response has already been affected', *CityPress*, viewed 17 February 2021, <https://city-press.news24.com/News/covid-19-sas-tb-response-has-already-been-affected-20200427>

Stuckler, D, Basu, S, McKee, M & Lurie, M 2011, 'Mining and risk of tuberculosis in sub-Saharan Africa', *American Journal of Public Health*, vol. 101, no. 3, pp. 524–530. https://doi.org/10.2105/AJPH.2009.175646

Stuckler, D, Steele, S, Lurie, M & Basu, S 2013, '"Dying for gold": The effects of mineral mining on HIV, tuberculosis, silicosis and occupational diseases in southern Africa', *International Journal of Health Services: Planning, Administration, Evaluation*, vol. 43, no. 4, pp. 639–649. https://doi.org/10.2190/HS.43.4.c

Swanepoel, DW 2006, 'Audiology in South Africa: Audiología en Sudáfrica', *International Journal of Audiology*, vol. 45, no. 5, pp. 262–266. https://doi.org/10.1080/14992020500485650

UNAIDS 2020, *Country factsheets: South Africa, 2019*, viewed 19 February 2021, <https://www.unaids.org/en/regionscountries/countries/southafrica>

Valente, M, Hosford-Dunn, H & Roeser, RJ (eds.) 2008, *Audiology: Treatment*, Thieme, New York.

World Health Organization (WHO) 2018a, *South Africa*, viewed 19 February 2021, <https://web.archive.org/web/20220121022851/https://www.who.int/nmh/countries/zaf_en.pdf>

World Health Organization (WHO) 2018b, *Country cooperation strategy at a glance*, viewed 19 February 2021, <https://apps.who.int/iris/bitstream/handle/10665/136874/ccsbrief_zaf_en.pdf;jsessionid=E4076B95B82E47064DB7DB3E8F795799?sequence=1>

World Health Organization (WHO) 2019, *Burden of disease: What is it and why is it important for safer food?*, viewed 19 February 2021, <https://web.archive.org/web/20220308071536/http://www.who.int/foodsafety/foodborne_disease/Q&A.pdf>

World Health Organization (WHO) 2020, *Global tuberculosis report 2020*, viewed 19 February 2021, <https://www.who.int/publications/i/item/9789240013131>

World Health Statistics 2015, *Part I: Health-related millenium development goals*, viewed 19 February 2021, <https://web.archive.org/web/20150701124941/http://www.who.int/gho/publications/world_health_statistics/EN_WHS2015_Part1.pdf?ua=1>

Yoon, JH, Hong, JS, Roh, J, Kim, CN & Won, JU 2015, 'Dose-response relationship between noise exposure and the risk of occupational injury', *Noise & Health*, vol. 17, no. 74, pp. 43–47. https://doi.org/10.4103/1463-1741.149578

Yoshioka, M, Uchida, Y, Sugiura, S, Ando, F, Shimokata, H, Nomura, H & Nakashima, T 2010, 'The impact of arterial sclerosis on hearing with and without occupational noise exposure: A population-based aging study in males', *Auris Nasus Larynx*, vol. 37, no. 5, pp. 558–564. https://doi.org/10.1016/j.anl.2010.02.006

Zaidi, AA, Dixon, J, Lupez, K, De Vries, S, Wallis, LA, Ginde, A & Mould-Millman, NK 2019, 'The burden of trauma at a district hospital in the Western Cape Province of South Africa', *African Journal of Emergency Medicine*, vol. 9, pp. 14–20. https://doi.org/10.1016/j.afjem.2019.01.007

Chapter 10

Aggarwal, K, Patel, R & Ravi, R 2020, 'Uptake of telepractice among speech-language therapists following COVID-19 pandemic in India', *Speech, Language and Hearing*, vol. 24, no. 4, pp. 228–234. https://doi.org/10.1080/2050571X.2020.1812034

Amedofu, GK 2002, 'Hearing-impairment among workers in a surface gold mining company in Ghana', *African Journal of Health Sciences*, vol. 9, no. 1, pp. 91–97. https://doi.org/10.4314/ajhs.v9i1.30759

Amedofu, GK 2007, 'Effectiveness of hearing conservation program at a large surface gold mining company in Ghana', *African Journal of Health Sciences*, vol. 14, no. 1, pp. 49–53. https://doi.org/10.4314/ajhs.v14i1.30846

American Academy of Audiology 1997, 'Scope of practice: Position statement', *Audiology Today*, vol. 9, no. 2, pp. 12–13. https://www.audiology.org/practice-resources/practice-guidelines-and-standards/scope-of-practice/

American Speech-Language-Hearing Association n.d., *Telepractice*, Practice Portal, viewed 18 February 2021, <www.asha.org/Practice-Portal/Professional-Issues/Telepractice/>

Amjad-Sardrudi, H, Dormohammadi, A, Golmohammadi, R & Poorolajal, J 2012, 'Effect of noise exposure on occupational injuries: A cross-sectional study', *Journal of Research in Health Sciences*, vol. 12, no. 2, pp. 101–104.

Audiology Australia 2015, *Submission to the medicare benefits schedule review taskforce consultation paper*, viewed 10 January 2020, <https://audiology.asn.au/Tenant/C0000013/Position%20Papers/Submissions/Audiology%20Australia%20Submission%20MBS%20review%20taskforce.pdf>

Audiology Australia 2020, *Teleaudiology: Position statement*, viewed 18 February 2021, <https://audiology.asn.au/Tenant/C0000013/AudA%20Position%20Statement%20Teleaudiology%202020%20Final(1).pdf>

Brennan-Jones, C, Eikelboom, R & Swanepoel, DW n.d., 'The open access atlas of otolaryngology, head and neck operative surgery', in J Fagan (ed.), *Telehealth for diagnosis of hearing loss: open access guide to audiology and hearing aids for otolaryngologists*, viewed 18 February 2021,

<https://vula.uct.ac.za/access/content/group/27b5cb1b-1b65-4280-9437-a9898ddd4c40/Telehealth%20for%20diagnosis%20of%20hearing%20loss.pdf>

Bush, ML, Thompson, R, Irungu, C & Ayugi, J 2016, 'The role of telemedicine in auditory rehabilitation: A systematic review', *Otology & Neurotology*, vol. 37, no. 10, a1236. https://doi.org/10.1097/MAO.0000000000001236

Chadambuka, A, Mususa, F & Muteti, S 2013, 'Prevalence of noise induced hearing loss among employees at a mining industry in Zimbabwe', *African Health Sciences*, vol. 13, no. 4, pp. 899–906. https://doi.org/10.4314/ahs.v13i4.6

Chamber of Mines of South Africa 2013, *Annual report 2012/2013*, viewed 18 February 2019, <https://www.mineralscouncil.org.za/industry-news/publications/annual-reports/send/15-archived/133-annual-report-2012-2013>

Chuhan-Pole, P, Dabalen, AL & Land, BC 2017, *Mining in Africa: Are local communities better off?*, World Bank Publications, viewed 10 September 2018, <https://openknowledge.worldbank.org/handle/10986/26110>

Claridge, R & Kroll, N 2021, 'Aural rehabilitation via telepractice during COVID-19: A global perspective on evolving early intervention practices', *International Journal of Telerehabilitation* 13(1), 6362. https://doi.org/10.5195/ijt.2021.6362

Coco, L, Davidson, A & Marrone, N 2020, 'The role of patient-site facilitators in teleaudiology: A scoping review', *American Journal of Audiology*, vol. 29, no. 3S, pp. 661–675. https://doi.org/10.1044/2020_AJA-19-00070

Daudt, HM, Van Mossel, C & Scott, SJ 2013, 'Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework', *BMC Medical Research Methodology*, vol. 13, a48. https://doi.org/10.1186/1471-2288-13-48

Department of Labour 2019, *Compensation for Occupational Injuries and Diseases Act, 1993 (Act No 130 Of 1993): Regulations on Noise Induced Hearing Loss for the Compensation Fund Made by the Minister Under Compensation for Occupational Injuries and Diseases Act, 1993*, viewed 16 February 2021, <https://www.mm3admin.co.za/documents/docmanager/editor/34/UserFiles/nihl%20document.pdf>

Dietz, R 2019, 'The future of hearing conservation', *CAOHC*, vol. 31, p. 2. https://www.caohc.org/updatearticles/2019/Update-issue2-19-DietzArticle.pdf

Edwards, AL, Dekker, JJ, Franz, RM, Van Dyk, T & Banyini, A 2011, 'Profiles of noise exposure levels in South African mining', *The Journal of The Southern African Institute of Mining and Metallurgy*, vol. 111, pp. 315–322.

Edwards, AL & Kritzingert, D 2012, 'Noise-induced hearing loss milestones: Past and future', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 112, no. 10, pp. 865–869.

Eikelboom, RH & Swanepoel, D 2016, 'International survey of audiologists' attitudes toward telehealth', *American Journal of Audiology*, vol. 25, no. 3S, pp. 295–298. https://doi.org/10.1044/2016_AJA-16-0004

Fabry, D 2010, 'Applications of telehealth for hearing care', *Audiology Today*, vol. 22, no. 5, pp. 18–25.

Fong, R, Tsai, CF & Yiu, OY 2021, 'The implementation of telepractice in speech language pathology in Hong Kong during the COVID-19 pandemic', *Telemedicine and e-Health*, vol. 27, no. 1, pp. 30–38. https://doi.org/10.1089/tmj.2020.0223

Givens, GD, Yao, JJ & Yao, D 2013, 'Innovation, disruption, and teleaudiology', *Technology & Innovation*, vol. 15, no. 3, pp. 253–258. https://doi.org/10.3727/194982413X13790020921942

Grobler, LM, Swanepoel, DW, Strauss, S, Becker, P & Eloff, Z 2020, 'Occupational noise and age: A longitudinal study of hearing sensitivity as a function of noise exposure and age in South African gold mine workers', *South African Journal of Communication Disorders*, vol. 67, no. 2, a687. https://doi.org/10.4102/sajcd.v67i2.687

Grogan-Johnson, S, Gabel, RM, Taylor, J, Rowan, LE, Alvares, R & Schenker, J 2011, 'A pilot exploration of speech sound disorder intervention delivered by telehealth to school–age children', *International Journal of Telerehabilitation*, vol. 3, no. 1, p. 31. https://doi.org/10.5195/ijt.2011.6064

Health Professions Council of South Africa (HPCSA) 2012, *Regulations relating to the undergraduate curricula and professional examinations in audiology*, viewed 18 February 2021, <https://www.hpcsa.co.za/Uploads/SLH/gg35350_nn387.pdf>

Hong, O, Kerr, MJ, Poling, GL & Dhar, S 2013, 'Understanding and preventing noise-induced hearing loss', *Disease-A-Month*, vol. 59, no. 4, pp. 110–118. https://doi.org/10.1016/j.disamonth.2013.01.002

Ida Institute 2019, *What are the six elements of person-centered care?*, viewed 18 February 2021, <https://idainstitute.com/what_we_do/news/detail/what_are_the_six_elements_of_person_centered_care/>

Jacobs, PG & Saunders, GH 2014, 'New opportunities and challenges for teleaudiology within Department of Veterans Affairs', *Journal of Rehabilitation Research and Development*, vol. 51, no. 5, pp. 7–12. https://doi.org/10.1682/JRRD.2014.04.0093

Kane-Berman, J 2017, *Diamonds and all that: The contribution of mining to South Africa*, Mining in SA: Then, now, and into the future – IRR, viewed 16 February 2021, <https://www.polity.org.za/article/diamonds-and-all-that-the-contribution-of-mining-to-south-africa-2017-02-16>

Khoza-Shangase, K 2021, 'Confronting realities to early hearing detection in South Africa', eds. K Khoza-Shangase & A Kanji, *Early detection and intervention in audiology: AN African perspective*, Wits University Press, Johannesburg, pp. 66–88.

Khoza-Shangase, K 2022, 'In pursuit of increasing the application of tele-audiology in South Africa: COVID-19 puts on the alert for patient site facilitator training', *South African Journal of Communication Disorders*, vol. 69, no. 2, a900. https://doi.org/10.4102/sajcd.v69i2.900

Khoza-Shangase, K & Moroe, N 2020, 'South African hearing conservation programmes in the context of tele-audiology: A scoping review', *South African Journal of Communication Disorders*, vol. 67, no. 2, p. 670. https://doi.org/10.4102/sajcd.v67i2.670

Khoza-Shangase, K, Moroe, NF & Edwards, A 2020, 'Occupational hearing loss in Africa: An interdisciplinary view of the current status', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Khoza-Shangase, K, Moroe, N & Neille, J 2021, 'Speech-language pathology and audiology in South Africa: Clinical training and service in the era of COVID-19', *International Journal of Telerehabilitation*, vol. 13, no. 1, a6376. https://doi.org/10.5195/ijt.2021.6376

Khoza-Shangase, K & Sebothoma, B 2022, 'Tele-audiology and preventive audiology: A capacity versus demand challenge imperative in South Africa', in K Khoza-Shangase (ed.), *Preventive audiology: An African perspective*, AOSIS Books, AOSIS Publishing (Pty) Ltd, Cape Town, pp. 21–40. https://doi.org/10.4102/aosis.2022.BK209.02

Kim, JA 2009, in R Wootton, NG Patil, RE Scott & K Ho (eds.), *Telehealth in the developing world*, Royal Society of Medicine Press/IDRC, London.

Krumm, M 2007, 'Audiology telemedicine', *Journal of Telemedicine and Telecare*, vol. 13, no. 5, pp. 224–229. https://doi.org/10.1258/135763307781458912

Krumm, M 2016, 'A review of contemporary tele-audiology literature', *Journal of Hearing Science*, vol. 6, no. 3, pp. 9–21. https://doi.org/10.7874/jao.2020.00500

Krupinski, E 2015, 'Innovations and possibilities in connected health', *Journal of American Academy of Audiology*, vol. 26, no. 09, pp. 761–767. https://doi.org/10.3766/jaaa.14047

Lam, JHY, Lee, SMK & Tong, X 2021, 'Parents' and students' perceptions of telepractice services for speech-language therapy during the COVID-19 pandemic: Survey study', *JMIR Pediatrics and Parenting*, vol. 4, no. 1, a25675. https://doi.org/10.2196/25675

MacLennan-Smith, F, Swanepoel, DW & Hall, III, JW 2013, 'Validity of diagnostic pure-tone audiometry without a sound-treated environment in older adults', *International Journal of Audiology*, vol. 52, no. 2, pp. 66–73. https://doi.org/10.3109/14992027.2012.736692

Mahomed-Asmail, F, Swanepoel, D & Eikelboom, RH 2016, 'Diagnostic hearing assessment in schools: Validity and time efficiency of automated audiometry', *Journal of the American Academy of Audiology*, vol. 27, no. 1, pp. 42–48. https://doi.org/10.3766/jaaa.15041

Maluleke, NP & Khoza-Shangase, K, submitted, 'Transitioning to online interviews during the COVID-19 pandemic: Exploring implications for family-centered early hearing detection and intervention (EHDI) services in South Africa', *Indian Journal of Otolaryngology and Head & Neck Surgery*.

Mansuri, B, Tohidast, SA, Mokhlesin, M, Choubineh, M, Zarei, M, Bagheri, R & Scherer RC 2021, 'Telepractice among speech and language pathologists: A KAP study during COVID-19 pandemic', *Speech, Language and Hearing*, vol. 25, no. 3, pp. 1–8. https://doi.org/10.1080/2050571X.2021.1976550

McGill, M & Dennard, Q 2021, 'Graduate students' perspectives toward telepractice at the COVID-19 global pandemic onset', *Perspectives of the ASHA Special Interest Groups*, vol. 6, no. 4, pp. 841–854. https://doi.org/10.1044/2021_PERSP-20-00231

McSwain, SD, Bernard, J, Burke, Jr, BL, Cole, SL, Dharmar, M, Hall-Barrow, J, Herendeen, N, Herendeen, P, Krupinski, EA, Martin, A, McCafferty, D, Mulligan, DA, North, S, Ruschman, J, Waller, M, Webster, K, Williams, S, Yamamoto, S & Yeager, B 2017, 'American Telemedicine Association operating procedures for pediatric telehealth', *Telemedicine and e-Health*, vol. 23, no. 9, pp. 699–706. https://doi.org/10.1089/tmj.2017.0176

Meinke, DK, Norris, JA, Flynn, BP & Clavier, OH 2017, 'Going wireless and boothless for hearing testing in industry', *International Journal of Audiology*, vol. 56, no. Suppl. 1, pp. 41–51. https://doi.org/10.1080/14992027.2016.1261189

MHSC 2015, 'Every mineworker returning from work unharmed every day: Striving for zero harm' – 2014 occupational health and safety summit milestones', *Occupational Health Southern Africa*, vol. 20, no. 1, p. 2.

Molini-Avejonas, RD, Rondon-Melo, S, De La Higuera Amato, CA & Samelli, AG 2015, 'A systematic review of the use of telehealth in speech, language and hearing sciences', *Journal of Telemedicine and Telecare*, vol. 21, no. 7, pp. 367–376. https://doi.org/10.1177/1357633X15583215

Morata, TC & Meinke, D 2016, 'Uncovering effective strategies for hearing loss prevention', *Acoustics Australia/Australian Acoustical Society*, vol. 44, no. 1, pp. 67–75. https://doi.org/10.1007/s40857-016-0044-9

Moroe, N & Khoza-Shangase, K 2018, 'Management of occupational noise induced hearing loss in the mining sector in South Africa: Where are the audiologists?', *Journal of Occupational Health*, vol. 60, no. 5, pp. 376–382. https://doi.org/10.1539/joh.2018-0020-OA

Moroe, NF & Khoza-Shangase, K 2020, 'Recent advances in hearing conservation programmes: A systematic review', *South African Journal of Communication Disorders*, vol. 67, no. 2, a675. https://doi.org/10.4102/sajcd.v67i2.675

Moroe, N, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise-induced hearing loss in the mining sector in Africa: A systematic review – 1994 to 2016', *Noise & Vibration Worldwide*, vol. 49, no. 5, pp. 181–190. https://doi.org/10.1177/0957456518781860

Moroe, NF, Khoza-Shangase, K, Madahana, M & Nyandoro, O 2020, 'Feedback-based noise management matrix in action', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a678. https://doi.org/10.4102/sajcd.v67i2.678

Mostaghaci, M, Mirmohammadi, SJ, Mehrparvar, AH, Bahaloo, M, Mollasadeghi, A & Davari, MH 2013, 'Effect of workplace noise on hearing ability in tile and ceramic industry workers in Iran: A 2-year follow-up study', *The Scientific World Journal*, vol. 2013, a923731. https://doi.org/10.1155/2013/923731

Mulwafu, W, Ensink, R, Kuper, H & Fagan, J 2017, 'Survey of ENT services in sub-Saharan Africa: Little progress between 2009 and 2015', *Global Health Action*, vol. 10, no. 1, a1289736. https://doi.org/10.1080/16549716.2017.1289736

Musiba, Z 2015, 'The prevalence of noise-induced hearing loss among Tanzanian miners', *Occupational Medicine*, vol. 65, no. 5, pp. 386–390. https://doi.org/10.1093/occmed/kqv046

Mutara, G & Mutanana, N 2015, 'An analysis of a hearing conservation programme (HCP) at a mining company in Zimbabwe', *Journal of Biology, Agriculture and Healthcare*, vol. 5, pp. 51–58.

Nagdee, N, Sebothoma, B, Madahana, M, Khoza-Shangase, K & Moroe, N 2022, 'Simulations as a mode of clinical training in healthcare professions: A scoping review to guide planning in speech-language pathology and audiology during the COVID-19 pandemic and beyond', *South African Journal of Communication Disorders*, vol. 69, no. 2, a905. https://doi.org/10.4102/sajcd.v69i2.905

Nandi, SS & Dhatrak, SV 2008, ‘Occupational noise-induced hearing loss in India’, *Indian Journal of Occupational and Environmental Medicine*, vol. 12, no. 2, p. 53. https://doi.org/10.4103/0019-5278.43260

Naudé, A & Bornman, J 2021, ‘Ethical considerations and tele-audiology in early hearing detection and intervention’, eds. K Khoza-Shangase & A Kanji, *Early detection and intervention in audiology: An African perspective*, Wits University Press, Johannesburg, p. 243.

Nelson, DI, Nelson, RY, Concha-Barrientos, M & Fingerhut, M 2005, ‘The global burden of occupational noise-induced hearing loss’, *American Journal of Industrial Medicine*, vol. 48, no. 6, pp. 446–458. https://doi.org/10.1002/ajim.20223

Norris, JA, Clavier, OH, Soli, SD & Meinke, DK n.d., *Mobile technology for booth-less audiometry*, viewed 16 February 2021, <https://creare-com.gitlab.io/tabsint/docs/references/2017-Internet-Audiology-WAHTS.pdf>

Ntlhakana, L, Nelson, G, Khoza-Shangase, K & Maposa, I 2021, ‘Predicting standard threshold shifts for occupational hearing loss among miners at a large-scale platinum mine in South Africa’, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 121, no. 8, pp. 397–404.

Picard, M, Girard, SA, Simard, M, Larocque, R, Leroux, T & Turcotte, F 2008, ‘Association of work-related accidents with noise exposure in the workplace and noise-induced hearing loss based on the experience of some 240,000 person-years of observation’, *Accident Analysis & Prevention*, vol. 40, no. 5, pp. 1644–1652. https://doi.org/10.1016/j.aap.2008.05.013

Pillay, M, Tiwari, R, Kathard, H & Chikte, U 2020, ‘Sustainable workforce: South African audiologists and speech therapists’, *Human Resources for Health*, vol. 18, no. 1, pp. 1–13. https://doi.org/10.1186/s12960-020-00488-6

Psarros, C & McMahon, C 2015, ‘Evaluating the benefits of a telepractice model’, eds. E Rushbrooke & KT Houston, *Telepractice in audiology*, Plural Publishing Inc, San Diego, pp. 47–90.

Ramkumar, V 2020, ‘Teleaudiology practices in Asia’, in S Hatzopoulos, A Ciorba & M Krumm (eds.), *Advances in audiology and hearing science*, Apple Academic Press, New York, pp. 365–384.

Ravi, R, Gunjawate, DR, Yerraguntla, K & Driscoll, C 2018, ‘Knowledge and perceptions of teleaudiology among audiologists: A systematic review’, *Journal of Audiology & Otology*, vol. 22, no. 3, pp. 120–127. https://doi.org/10.7874/jao.2017.00353

Rikhardsson, PM 2004, ‘Accounting for the cost of occupational accidents’, *Corporate Social Responsibility and Environmental Management*, vol. 11, no. 2, pp. 63–70. https://doi.org/10.1002/csr.52

Ritzel, DO & McCrary-Quarles, AR 2008, ‘Hearing loss prevention and noise control’, *Umwelt und Gesundheit*, vol. 1, pp. 22–29.

Rushbrooke, E 2015, ‘Models of service delivery: What should we consider?’, in E Rushbrooke & KT Houston (eds.), *Telepractice in audiology*, Plural Publishing, Inc, San Diego, pp. 23–45.

Safe Work Australia 2010, ‘Occupational noise-induced hearing loss in Australia’, in *Overcoming barriers to effective noise control and hearing loss prevention*, Safe Work Australia, viewed 10 February 2021, <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwj8kJGr5dDjAhXCVBUIHR_ClEQFjAAegQIAxAC&url=http%3A%2F%2Fwww.hearingservices.gov.au%%202Fwps%2Fwcm%2Fconnect%2Fhso%2Fc4b9decf-af99-4375-a49f6445ce589f01%2FOccupational%2Bnoise.docx%3FMOD%3DAJPERES&usg=AOvVaw2nDzZbvTR%20kSlIANpzEJQlf>

Saunders, E (ed.) 2019, *Tele-audiology and the optimization of hearing healthcare delivery*, IGI Global, Hershey.

Sebothoma, B, Khoza-Shangase, K, Masege, D & Mol, D 2021, ‘The use of tele practice in assessment of middle ear function in adults living with HIV during the COVID-19 pandemic’, *Indian Journal of Otolaryngology and Head & Neck Surgery*, vol. 5, pp. 1–8. https://doi.org/10.1007/s12070-021-02836-x

Si, S, Lewkowski, K, Fritschi, L, Heyworth, J, Liew, D & Li, I 2020, 'Productivity burden of occupational noise-induced hearing loss in Australia: A life table modelling study', *International Journal of Environmental Research and Public Health*, vol. 17, no. 13, a4667. https://doi.org/10.3390/ijerph17134667

Siegfried, N, Wilkinson, T & Hofman, K 2017, 'Where from and where to for health technology assessment in South Africa? A legal and policy landscape analysis', eds. A Padarath & P Barron, *South African health review 2017*, Health Systems Trust, viewed 18 February 2021, <https://www.cabdirect.org/globalhealth/abstract/20183060887>

Stephens, M 2013, *Tele-audiology as a means to increasing access to audiologic services*, viewed 14 February 2021, <https://kb.osu.edu/handle/1811/54574>

Strauss, S, Swanepoel, DW, Becker, P, Eloff, Z & Hall, JWI 2012, 'Prevalence and degree of noise induced hearing loss in South African gold miners', *International Journal of Audiology*, vol. 18, no. 6, pp. 20–25.

Swanepoel, D, Maclennan-Smith, F & Hall, JW 2013, 'Diagnostic pure-tone audiometry in schools: Mobile testing without a sound-treated environment', *Journal of the American Academy of Audiology*, vol. 24, no. 10, pp. 992–1000. https://doi.org/10.3766/jaaa.24.10.10

Swanepoel, DW, Clark, JL, Koekemoer, D, Hall, 3rd JW, Krumm, M, Ferrari, DV, McPherson, B, Olusanya, BO, Mars, M, Russo, I & Barajas, JJ 2010, 'Telehealth in audiology: The need and potential to reach underserved communities', *International Journal of Audiology*, vol. 49, no. 3, pp. 195–202. https://doi.org/10.3109/14992020903470783

Swanepoel, DW, Matthysen, C, Eikelboom, RH, Clark, JL & Hall, 3rd, JW 2015, 'Pure-tone audiometry outside a sound booth using earphone attenuation, integrated noise monitoring, and automation', *International Journal of Audiology*, vol. 54, no. 11, pp. 777–785. https://pubmed.ncbi.nlm.nih.gov/26514954/

Taylor, B 2020, 'Audiology's third pillar: Comprehensive follow-up care and counseling for those who choose to self-direct their care', viewed 16 February 2021, <https://www.intechopen.com/chapters/70208>

Teke, Z 2017, 'Probe into struggles of ex-miners', *Sunday Tribune*, viewed 18 February 2021, <https://web.archive.org/web/20211125140639/https://www.iol.co.za/sunday-tribune/news/probe-into-struggles-of-ex-miners-11515422>

Thorne, PR 2006, *Best practice in noise-induced hearing loss management and prevention: A review of literature, practices and policies for the New Zealand context*, Accident Compensation Corporation, viewed 18 February 2021, <https://dspace.nal.gov.au/xmlui/bitstream/handle/123456789/481/Best%20practice%20in%20noise%20-%20induced%20hearing%20loss%20management%20and%20prevention.pdf?sequence=1&isAllowed=y>

US Occupational Safety and Health Administration (OSHA) 2002, *Hearing conservation*, viewed 16 February 2021, <https://www.osha.gov/Publications/osha3074.pdf>

Wade, VA, Eliott, JA & Hiller, JE 2012, 'A qualitative study of ethical, medico-legal and clinical governance matters in Australian telehealth services', *Journal of Telemedicine and Telecare* 18(2), 109–114. https://doi.org/10.1258/jtt.2011.110808

Wade, VA, Eliott, JA & Hiller, JE 2014, 'Clinician acceptance is the key factor for sustainable telehealth services', *Qualitative Health Research*, vol. 24, no. 5, pp. 682–694. https://doi.org/10.1177/1049732314528809

Waibel, KH, Garner, SJ, Carter, B, Bojicic, I & Smith, R 2017, 'Outcomes of a military regional multispecialty synchronous telehealth platform and the importance of the dedicated patient presenter', *US Army Medical Department Journal*, vol. 2–17, pp. 1–8. http://www.ncbi.nlm.nih.gov/pubmed/28853112

Wolfgang, K 2019, 'Risks, rewards of teleaudiology', *The Hearing Journal*, vol. 72, no. 1, pp. 28–30. https://doi.org/10.1097/01.HJ.0000552746.59241.4a

World Health Organization (WHO) 2018a, *Prevention of blindness and deafness*, viewed 18 February 2021, <http://www.emro.who.int/entity/blindness/index.html>

World Health Organization (WHO) 2018b, *Addressing the rising prevalence of hearing loss*, viewed 17 February 2021, <https://apps.who.int/iris/handle/10665/260336>

Yongbing, S & Martin, W 2013, ‘Noise induced hearing loss in China: A potentially costly public health issue’, *Journal of Otology*, vol. 8, no. 1, pp. 51–56. https://doi.org/10.1016/S1672-2930(13)50007-9

Zungu, LI, Edwards, AL, Milanzi, LA, Khoza, NN & Letsoalo, MS 2015, ‘Evaluation of the current practices of noise-induced hearing loss (NIHL) awareness training in the South African mining industry’, *Occupational Health Southern Africa*, vol. 21, no. 1, pp. 11–17.

Chapter 11

Abdallah, O, Ageeb, RA, Elkhalifa, WHI, Zolezzi, M, El-Awaisi, A, Diab, MI & Awaisu, A 2020, ‘Evaluating prescribing competencies covered in a Canadian-accredited undergraduate pharmacy program in Qatar: A curriculum mapping process’, *MC Medical Education*, vol. 20, no. 1, p. 253. https://doi.org/10.1186/s12909-020-02109-1

Amedofu, GK 2007, ‘Effectiveness of hearing conservation program at a large surface gold mining company in Ghana’, *African Journal of Health Sciences*, vol. 14, no. 1, pp. 49–53. https://doi.org/10.4314/ajhs.v14i1.30846

Amedofu, GK & Fuente, A 2008, ‘Occupational hearing loss in developing countries’, eds. B Mcpherson & R Bbouillette, *Audiology in developing countries*, Nova Science Publishers, Inc, Hauppauge, New York, pp. 189–221.

Amiri, F, Zamanian, Z., Mani, A & Hasanzadeh, J 2015, ‘Effects of combined exposure to noise, heat and lighting on cognitive performance’, *Iran Occupational Health*, vol. 12, no. 5, pp. 10–20.

Amjad-Sardrudi, H, Dormohammadi, A, Golmohammadi, R & Poorolajal, J 2012, ‘Effect of noise exposure on occupational injuries: A cross-sectional study’, *Journal of Research in Health Sciences*, vol. 12, pp. 101–104.

Attarchi, MS, Sadeghi, Z, Faezeh, D, Sohrabi, MM & Saber, M 2010, ‘Assessment of hearing standard threshold shift based on audiometric findings in steel company workers’, *Iranian Red Crescent Medical Journal*, vol. 12, pp. 644–649.

Audiology Australia 2020, *Teleaudiology: Position statement*, viewed 26 February 2021, <https://audiology.asn.au/Tenant/C0000013/AudA%20Position%20Statement%20Teleaudiology%202020%20Final(1).pdf>

Basner, M, Babisch, W, Davis, A, Brink, M, Clark, C, Janssen, S & Stansfeld, S 2014, ‘Auditory and non-auditory effects of noise on health’, *Lancet*, vol. 383, no. 9925, pp. 1325–1332. https://doi.org/10.1016/S0140-6736(13)61613-X

Biabani, A, Aliabadi, M, Golmohammadi, R & Farhadian, M 2017, ‘Individual fit testing of hearing protection devices based on microphone in real ear’, *Safety and Health at Work*, vol. 8, no. 4, pp. 364–370. https://doi.org/10.1016/j.shaw.2017.03.005

Booi, M 2020, ‘Learning more from the hearing conservation programme’s medical surveillance data’, *Occupational Health Southern Africa*, vol. 26, no. 4, pp. 183–184.

Bowens, A 2018a, *Evidence updates on risk factors for occupational noise-induced hearing loss (ONIHL) update 3: Genetic factors*, viewed 26 February 2021, <https://www.acc.co.nz/assets/research/63e6836c44/ONIHL-evidence-genetics.pdf>

Bowens, A 2018b, *Evidence updates on risk factors for occupational noise-induced hearing loss (ONIHL) update 1: Exposure to solvents with or without noise*, viewed 26 February 2021, <https://www.acc.co.nz/assets/research/23160770fb/ONIHL-evidence-solvents.pdf>

Brauch, R 2017, ‘Tech advances are reinventing hearing conservation programs: Open your ears’, *Industrial Safety and Hygiene News*, viewed 26 February 2021, <https://www.ishn.com/articles/105847-tech-advances-are-reinventing-hearing-conservation-programs>

Brits, J, Strauss, S, Eloff, Z, Becker, PJ & Swanepoel, DW 2012, ‘Hearing profile of gold miners with and without tuberculosis’, *Occupational and Environmental Medicine*, vol. 69, no. 4, pp. 243–249. https://doi.org/10.1136/oemed-2011-100106

Cawood, FT 2011, ‘Threats to the South African minerals sector: An independent view on the investment environment for mining’, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 7, pp. 469–474. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532011000700006&lng=en&nrm=iso

Chen, KH, Su, SB & Chen, KT 2020, ‘An overview of occupational noise-induced hearing loss among workers: Epidemiology, pathogenesis, and preventive measures’, *Environmental Health and Preventive Medicine*, vol. 25, no. 1, pp. 1–10. https://doi.org/10.1186/s12199-020-00906-0

Concha-Barrientos, M, Campbell-Lendrum, D & Steenland, K 2004, *Occupational noise: Assessing the burden of disease from work-related hearing impairment at national and local levels*, Environmental Burden of Disease Series, No. 9, viewed 26 February 2021, <https://apps.who.int/iris/handle/10665/43001>

De Jong, MA, Adelman, C, Rubin, M & Sohmer, H 2012, ‘Combined effects of salicylic acid and furosemide and noise on hearing’, *Journal of Occupational Medicine and Toxicology*, vol. 7, no. 1, pp. 1–6. https://doi.org/10.1186/1745-6673-7-1

De Jonge, P, Huyse, FJ & Stiefel, FC 2006, ‘Case and care complexity in the medically ill’, *The Medical Clinics of North America*, vol. 90, no. 4, pp. 679–692. https://doi.org/10.1016/j.mcna.2006.04.005

Dekker, JJ, Edwards, AL, Franz, RM, Van Dyk, T & Banyini, A 2011, ‘Meeting the milestones: Are South African small-to medium-scale mines up to the task?’, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 5, pp. 309–313. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532011001700002&lng=en&tlng=en

Edwards, A & Kritzinger, D 2012, ‘Noise-induced hearing loss milestones: Past and future’, *South African Institute of Mining and Metallurgy*, vol. 112, pp. 865–869. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532012001000006&lng=en&nrm=iso

Edwards, A, 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’, *Occupational Health Southern Africa*, vol. 21, no. 1, pp. 11–17. http://reference.sabinet.co.za/document/EJC166085

Edwards, AL, Dekker, JJ, Franz, RM, Van Dyk, T & Banyini, A 2011, ‘Profiles of noise exposure levels in South African mining’, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 5, pp. 315–322. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532011001700003&lng=en&tlng=en

Golmohammadi, R & Darvishi, E 2019, ‘The combined effects of occupational exposure to noise and other risk factors – a systematic review’, *Noise & Health*, vol. 21, no. 101, pp. 125–141. https://doi.org/10.4103/nah.NAH_4_18

Hager, L 2011, ‘Fit-testing hearing protectors: An idea whose time has come’, *Noise and Health*, vol. 13, no. 51, pp. 147–151. https://doi.org/10.4103/1463-1741.77217

Hong, O, Kerr, MJ, Poling, GL & Dhar, S 2013, ‘Understanding and preventing noise-induced hearing loss’, *Disease-a-Month*, vol. 59, no. 4, pp. 110–118. https://doi.org/10.1016/j.disamonth.2013.01.002

International Labour Organization 2014, *Safety and health at work: A vision for sustainable prevention*, viewed 26 February 2021, <https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_301214.pdf>

Kahan, E & Ross, E 1994, ‘Knowledge and attitudes of a group of South African mine workers towards noise induced hearing loss and the use of hearing protective devices’, *South African Journal of Communication Disorders*, vol. 41, no. 1, pp. 37–47. https://doi.org/10.4102/sajcd.v41i1.255

Kew, G 2018, *A review of current practice & a need for new ideas to solve an old problem: SASOM Conference Occupational Medicine Specialists*, 22–23 June 2018, Kempton Park.

Khoza-Shangase, K 2020a, ‘Burden of disease: a scoping review of HIV/AIDS and TB in occupational noise-induced hearing loss’, *South African Journal of Communication Disorders*, vol. 67, no. 2, a669. https://doi.org/10.4102/sajcd.v67i2.669

Khoza-Shangase, K 2020b, 'Hearing function of gold miners with and without a history of tuberculosis treatment: A retrospective data review', *Brazilian Journal of Otorhinolaryngology*, vol. 86, no. 3, pp. 294–299. https://doi.org/10.1016/j.bjorl.2018.12.003

Khoza-Shangase, K 2022, 'Preventive audiology: Ramping up efforts towards an ear and hearing healthy nation', ed. K Khoza-Shangase, *Preventive audiology: An African perspective*, AOSIS Books, AOSIS Publishing (Pty) Ltd, Cape Town, pp. 1–20. https://doi.org/10.4102/aosis.2022.BK209.01

Khoza-Shangase, K, Moroe, N & Edwards, A 2020, 'Occupational hearing loss in Africa: An interdisciplinary view of the current status', *South African Journal of Communication Disorders*, vol. 67, no. 2, a700. https://doi.org/10.4102/sajcd.v67i2.700

Khoza-Shangase, K, Moroe, N & Neille, J 2021, 'Speech-language pathology and audiology in South Africa: Clinical training and service in the era of COVID-19', *International Journal of Telerehabilitation*, vol. 13, no. 1, a6376. https://doi.org/10.5195/ijt.2021.6376

Kuipers, P, Kendall, E, Ehrlich, C, McIntyre, M, Barber, L, Amsters, D. et al. 2011, *Complexity and health care: health practitioner workforce, services, roles, skills and training to respond to patients with complex needs*, Clinical Education and Training Queensland, viewed 17 April 2018, <https://www.health.qld.gov.au/__data/assets/pdf_file/0027/150768/complexcarefull1.pdf>

Lin, FR 2012, 'Hearing loss in older adults: Who's listening?', *The Journal of the American Medical Association*, vol. 307, no. 11, pp. 1147–1148. https://doi.org/10.1001/jama.2012.321

Liu, S, Nkrumah, ENK, Akoto, LS, Gyabeng, E & Nkrumah, E 2020, 'The state of occupational health and safety management frameworks (OHSMF) and occupational injuries and accidents in the Ghanaian oil and gas industry: Assessing the mediating role of safety knowledge', *BioMed Research International*, vol. 2020, a6354895. https://doi.org/10.1155/2020/6354895

Masterson, EA, Bushnel, PT, Themann, CL & Morata, TC 2016, 'Hearing impairment among noise-exposed workers – United States, 2003–2012', *Morbidity and Mortality Weekly Report*, vol. 65, no. 15, pp. 389–394. https://doi.org/10.15585/mmwr.mm6515a2

Mbazima, N 2020, 'Reviving a declining mining industry', *Viewpoints*, viewed 23 February 2021, <https://www.africaportal.org/publications/reviving-declining-mining-industry/>

Mele, C, Pels, J & Polese, F 2010, 'A brief review of systems theories and their managerial applications', *Service Science*, vol. 2, no. 1–2, pp. 126–135. https://doi.org/10.1287/serv.2.1_2.126

Moroe, N 2020, 'Occupational noise induced hearing loss in the mining sector in South Africa: Perspectives from occupational health practitioners on how mineworkers are trained', *South African Journal of Communication Disorders*, vol. 67, no. 2, a676. https://doi.org/10.4102/sajcd.v67i2.676

Moroe, N & Khoza-Shangase, K 2018, 'Research into occupational noise induced hearing loss in South African large-scale mines: access denied?', *AAS Open Research*, vol. 1, p. 4. https://doi.org/10.12688/aasopenres.12829.1

Moroe, NF & Khoza-Shangase, K 2022, 'Complexities with hearing conservation programmes in South African mines: Applying complex interventions theory', in K Khoza-Shangase (ed.), *Complexities and challenges in preventive audiology: An African perspective,* AOSIS Books, AOSIS Publishing (Pty) Ltd, Cape Town, pp. 125–140. https://doi.org/10.4102/aosis.2022.BK311.08

Moroe, N, Khoza-Shangase, K, Kanji, A & Ntlhakana, L 2018, 'The management of occupational noise–induced hearing loss in the mining sector in Africa: A systematic review – 1994 to 2016', *Noise & Vibration Worldwide*, vol. 49, no. 5, pp. 181–190. https://doi.org/10.1177/0957456518781860

Moroe, NF 2018, *Occupational noise-induced hearing loss in South African large-scale mines: From policy formulation to implementation and monitoring*, viewed 26 February 2021, <https://hdl.handle.net/10539/27177>

Moroe, NF & Khoza-Shangase, K 2020, 'Recent advances in hearing conservation programmes: A systematic review', *South African Journal of Communication Disorders*, vol. 67, no. 2, a675. https://doi.org/10.4102/sajcd.v67i2.675

Moroe, NF, Khoza-Shangase, K, Madahana, MCI & Nyandoro, OTC 2019, 'A feedback-based noise monitoring model: A proposed model of managing occupational noise induced hearing loss in the mining sector in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 119, no. 7, pp. 671–679. https://doi.org/10.17159/24119717/18/016/2019

Musiba, Z 2020, 'Classification of audiograms in the prevention of noise-induced hearing loss: A clinical perspective', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a691. https://doi.org/10.4102/sajcd.v67i2.691

Mutara, G & Mutanana, N 2015, 'An analysis of a hearing conservation programme (HCP) at a mining company in zimbabwe', *Journal of Biology, Agriculture and Healthcare*, vol. 5, no. 12, pp. 51–58.

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', *Occupational Health Southern Africa*, vol. 21, pp. 10–15.

Ntlhakana, L, Khoza-Shangase, K & Nelson, G 2020a, 'Occupational noise-induced hearing loss in platinum miners: What do the data tell us?', *Occupational Health Southern Africa*, vol. 26, no. 1, pp. 8–14. https://doi.org/10.17159/2411-9717/1318/2021

Ntlhakana, L, Nelson, G & Khoza-Shangase, K 2020b, 'Estimating miners at risk for occupational noise-induced hearing loss: A review of data from a South African platinum mine', *The South African Journal of Communication Disorders*, vol. 67, no. 2, a677. https://doi.org/10.4102/sajcd.v67i2.677

Ntlhakana, L, Nelson, G, Khoza-Shangase, K & Maposa, I 2021, 'Predicting standard threshold shifts for occupational hearing loss among miners at a large-scale platinum mine in South Africa', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 121, no. 8, pp. 397–404. https://doi.org/10.17159/2411-9717/1318/2021

Nupen, L 2020, *Mining in South Africa: Industry challenges in 2020*, viewed 26 February 2021, <https://www.miningreview.com/gold/mining-in-south-africa-industry-challenges-in-2020/>

Pillay, M 2020, 'Chemicals, noise and occupational hearing health in South Africa: A mapping study', *South African Journal of Communication Disorders*, vol. 67, no. 2, a693. https://doi.org/10.4102/sajcd.v67i1.693

Pillay, M & Manning, WG 2020, 'A critical analysis of the current South African occupational health law and hearing loss', *South African Journal of Communication Disorders*, vol. 67, no. 2, a694. https://doi.org/10.4102/sajcd.v67i2.694

Seixas, NS, Neitzel, R, Stover, B, Sheppard, L, Daniell, B, Edelson, J & Meischke, H 2011, 'A multi-component intervention to promote hearing protector use among construction workers', *International Journal of Audiology*, vol. 50, no. sup1, pp. 46–56. https://doi.org/10.3109/14992027.2010.525754

Seixas, NS, Neitzel, R, Stover, B, Sheppard, L, Feeney, P, Mills, D & Kujawa, S 2012, '10-year prospective study of noise exposure and hearing damage among construction workers', *Occupational and Environmental Medicine*, vol. 69, no. 9, pp. 643–650. https://dx.doi.org/10.1136%2Foemed-2011-100578

Strauss, S, Swanepoel, DW, Becker, P, Eloff, Z & Hall, JW 3rd 2014, 'Noise and age-related hearing loss: a study of 40 123 gold miners in South Africa', *International Journal of Audiology*, vol. 53, no. 2, pp. 66–75. https://doi.org/10.3109/14992027.2013.865846

World Health Organization (WHO) 2018, *Country cooperation strategy at a glance*, viewed 26 February 2021, <https://apps.who.int/iris/bitstream/handle/10665/136874/ccsbrief_zaf_en.pdf;jsessionid=E4076B95B82E47064DB7DB3E8F795799?sequence=1>

Wolfgang, K 2019, 'Risks, rewards of teleaudiology', *The Hearing Journal*, vol. 72, no. 1, pp. 28–30. https://doi.org/10.1097/01.HJ.0000552746.59241.4a

Yerramilli, P 2015, *South Africa's quadruple burden of disease*, viewed 26 February 2021, <https://www.openhealthnews.com/story/2015-03-28/south-africa%E2%80%99s-quadruple-burden-disease>

Index

This book deliberates a clearer understanding and about the characterisation of occupational noise-induced hearing loss (ONIHL). This complex occupational health condition requires the adoption of the complex interventions approach to managing the challenges which confront hearing conservation programmes (HCPs) within the African context. Guided by the systems theory, to be realistic about implementing, monitoring and evaluating outcomes of HCPs within the African mining context, this book is a call for a paradigm shift in the assessment and management of ONIHL and HCPs in African mines. This book equips occupational healthcare researchers involved in the management of ONIHL and implementation of HCPs with evidence that allows for contextually-relevant best practice in mines, particularly mines located in low-and-middle-income countries (LMICs). This best practice is multidisciplinary in nature and engages all stakeholders from all relevant sectors with the goal to adopt a preventive audiology approach to ONIHL, rather than the compensation-oriented approach that is currently prevalent. This book is a research-driven contribution to the occupational health and safety (OHS) field with ONIHL as a focus case study. It provides contemporary contextually-relevant and responsive evidence related to ONIHL and HCPs in LMICs, with a very specific focus on the South African context. In this book, ONIHL and HCPs are comprehensively discussed, with careful considerations of the challenges and complexities that accompany HCPs implementation, specifically applicable to LMICs, although also applicable globally. In order to ensure an Afrocentric contribution to the world of evidence, the book offers potential solutions and recommendations for all challenges identified, including engaging carefully and deliberately with local evidence, local contexts, and local policies and regulations.

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This is an insightful and comprehensive book – a must-read for every scholar in the mining industry and also in health and safety. It provides the reader with some history of the mining industry in South Africa, explaining why it is so vital for the country, as well as the typical workforce. This information forms the foundation for the importance of ONIHL. The book also addresses the steady rise in technology and how the 4IR and hearing assessments may impact the mining industry. One of the best takeaway messages from this book is the fact that the authors are calling for a paradigm shift in the planning and management of hearing conservation programmes: the focus should as far as possible be on prevention and not only compensation. The authors highlight the integral part audiologists play in hearing conservation programmes, and also illustrate how few are actively involved in these programmes.

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