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Stakeholder perspectives on hearing conservation programmes in the South African mining sector: A qualitative study

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Abstract

Purpose Stakeholders play a crucial role in the success of complex interventions, such as hearing conservation programmes (HCPs), where their active participation directly impacts outcomes. This study aimed to investigate the views of various stakeholders, involved in occupational noise management, in the mining sector in South Africa.

Methods A cross-sectional qualitative study was conducted, recruiting 16 participants through purposive and snowball sampling techniques. Participants represented diverse roles, including Mine Health and Safety officials, audiologists, ventilation and occupational health engineers and an occupational hygiene assistant. In-depth interviews were conducted to gather data, which were later analysed using inductive thematic analysis to identify emerging themes.

Results The in-depth interviews revealed six prominent themes that shed light on both the facilitators and barriers to achieving desired milestones in the implementation of HCPs. These themes were crisis management; some are more equal than others; we have tried, but then reality intervenes; cost of an individual's hearing; knowledge is power; and show and tell.

Conclusion Achieving milestones requires a comprehensive and systematic approach, fostering collaborative engagement among all stakeholders in the mining industry. By viewing and treating HCPs as complex interventions, occupational healthcare can be improved for individuals exposed to excessive noise in the workplace. The study highlights the need for careful consideration of stakeholder perspectives to ensure the feasibility and effectiveness of interventions aimed at eliminating excessive noise in the mining industry.

Keywords Stakeholders, Mine health and safety milestones, Occupational noise, Hearing conservation programmes, Complex interventions

Introduction

Occupational noise-induced hearing loss (ONIHL) is a widespread occupational disease that occurs as a result of prolonged exposure to excessive noise in the workplace [6, 22]. It is currently recognized as the most prevalent occupational disease globally [24, 25]. According to the latest Global Burden of Disease report in 2019, approximately 1.57 billion people, which is about 20.3% of the world population, suffer from some form of hearing loss, with around 5% attributed to noise-induced hearing loss [40]. ONIHL is estimated to account for 7–21% of the overall burden of adult hearing loss worldwide [48]. It ranks as the second most common cause of hearing loss, surpassed only by presbycusis, and it tends to affect adult men more frequently [22]. The economic impact of ONIHL is substantial, both at the individual and societal levels, leading to healthcare system burdens and productivity losses [24, 40, 48].

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Fortunately, ONIHL is preventable [6, 13, 34, 35, 48] through hearing conservation interventions, commonly known as hearing conservation programs (HCPs), which align with the hierarchy of control [34, 35]. The hierarchy of noise control emphasizes that the primary defence against occupational noise exposure should be engineering controls. Noise controls involve three methods: controlling the noise at its source, controlling the noise along its transmission path and controlling the noise at the receiver's location [12]. This preventive strategy aims to eliminate the source of noise, often achieved through the use of quieter equipment, a concept known as buying quiet [52]. When engineering controls are not feasible, administrative controls are the next line of defence, aiming to minimize the impact of noise exposure on workers. Administrative controls involve measures such as limiting the duration of noise exposure through job rotation or task modifications [1, 4]. Finally, hearing protection devices serve as the last line of defence against noise exposure [16]. While seemingly passive, they are practical and effective when correctly sized, properly fitted and adequately maintained [21].

Hearing conservation programs are complex interventions comprised of various interacting components or pillars that function both independently and interdependently [34, 35]. As with complex intervention, HCPs require active theories , and they are able to achieve their effect through the active involvement and engagement of individuals. They involve long journeys and are nonlinear in their implementation chains, as they can reverse direction. HCPs are fragile and embedded in multiple social systems and are prone to be borrowed. Lastly, they are open systems that feed back on themselves [34, 35, 43]. As such, the effectiveness of HCPs is heavily influenced by behaviours, behaviour parameters and methods of organizing those behaviours, which can have an impact at the individual, organizational or population level [34, 35]. This means that HCPs are highly susceptible to the behaviour of various stakeholders and the environmental context in which they are implemented.

Despite the existence of an evidence base and the effectiveness of hearing conservation in eliminating or minimizing the impact of occupational noise exposure [27, 31], the prevalence and incidence of ONIHL continue to rise globally [28, 29, 38, 51, 54]. Moreover, some studies have reported success with hearing conservation programs, while others have documented low success rates. According to Pfadenhauer et al. [44], the effectiveness and success of complex interventions such as HCPs critically depend on their implementation within a specific context. In other words, effectiveness, implementation and context are inextricably linked.

In South Africa, hearing conservation programs (HCPs) were formally introduced in 1994 following the recommendations of the Leon Commission of Enquiry into Health and Safety in the mining sector. The commission proposed provisions under section 4.17.1–14.17.4 to control noise and establish a hearing conservation program for workers exposed to noise levels exceeding 85 dB(A). Additionally, the use of personal protective equipment was mandated in mines [49]. The main objective of these provisions was to enhance the monitoring of standards and practices, promote adherence to HCPs and improve the control of health risks [49].

Later, in 2003, the South African Mine Health and Safety Council (MHSC), which consists of representatives from the state, labour and employers, introduced the MHSC 2003 ONIHL milestones in the mining industry. The first milestone aimed to eliminate hearing deterioration greater than 10% by December 2008 in individuals exposed to excessive occupational noise. The second milestone aimed to minimize the total noise emitted by any equipment to less than 110 dB(A) at any point in the workplace by December 2013 [8, 9]. However, in 2013, a review of these milestones revealed that they had not achieved the intended outcomes [8, 9]. As a result, the milestones were revised in 2014, stating that, by December 2024, the total operational or process noise emitted by any equipment should not exceed a milestone sound pressure level of 107 dB(A). Furthermore, by December 2016, no employee's standard threshold shift (STS) should exceed 25 dB from the baseline when averaged at 2000, 3000 and 4000 Hz in one or both ears [30]. The focus on STS was a preventive measure aligned with the mine health and safety mandate. However, in some mining houses, this milestone has not yielded the desired outcomes.

A systematic review examining the factors contributing to the failure of the hearing conservation interventions in South Africa revealed several issues. Firstly, there has been limited research conducted on HCPs, not only in South Africa but also in sub-Saharan Africa. Additionally, the studies that have been conducted often lack a comprehensive approach and are conducted in a piecemeal fashion. There is a poor understanding of the role of various components or pillars of the HCP, and many studies have small sample sizes [32]. Furthermore, critical stakeholders in the management of occupational noise, such as audiologists and workers exposed to excessive noise, are often excluded in the conceptualization, implementation, evaluation and monitoring of the implemented interventions (Moroe and Khoza-Shangase 2018).

Other studies have highlighted certain challenges in the implementation of HCPs in the mining industry. There is a heavy emphasis on the use of personal

hearing protection devices as a strategy to address ONIHL, despite the hierarchy of noise control recommending their use as a last resort if engineering and administrative measures fail [16–20]. Additionally, there is a tendency for the industry to downplay the importance of engineering controls, such as buying quieter equipment. Education and awareness campaigns on the impact of ONIHL are also lacking [10, 34, 35]. Overall, HCPs are complex interventions that are influenced by the attitudes of various stakeholders and the implementation environment [32]. Therefore, there is a need for studies to investigate stakeholder engagement in HCP implementation, as the participation of stakeholders greatly influences the outcomes of these interventions.

Material and methods

Objective

The current study is part of a bigger study titled: Occupational Noise-Induced Hearing Loss in South African Mines: From Policy Formulation to Implementation and Monitoring. The objective of this portion of the study was to explore the views of stakeholders on the factors that contributed to the failure of the MHSC ONIHL milestones.

Research methods

A qualitative research strategy was undertaken to understand and illuminate the views of stakeholders on the MHSC ONIHL milestones. A qualitative approach was chosen for its naturalistic approach in seeking to understand phenomena in context-specific settings, without the influence of the researcher, thereby eliminating the manipulation of and allowing for the natural unfolding of the phenomena of interest [15, 42]. Furthermore, qualitative research is concerned with illuminating, understanding and exploring the phenomena in its context [19], which was the aim of the current study.

Sampling strategy

A non-probability purposive sampling strategy was utilized to recruit potential participants who met the inclusion criteria [41]. The Mine Health and Safety Council as well as the audiologists were identified from websites of companies affiliated with the South African mining industry. These potential participants were contacted via email and telephonically and thereafter were asked to participate in this study. Additionally, they were further asked to suggest other participants who could be invited to take part in the study. Occupational health practitioners were recruited from a mine in the Limpopo Province. Attempts were made to recruit participants from various mines across different commodities; however, access was denied [33, 36].

Inclusion criteria

- All participants were required to have been employed by or contracted to the mines for 6 months or more.
- Participants had to be aware and active in any stage from formulation to implementation of HCPs in the mining industry.

Sample size

A total sample of 16 participants was obtained and interviewed for the study (Table 1). Three participants were excluded, as they had less than 6 months' experience of being involved in the management of ONIHL in the mining sector. Participants compromised six representatives from the state, labour and employers; seven audiologists; two ventilation and occupational health engineers; and one occupational hygienist.

Data collection

Interviews

In-depth qualitative interviews were conducted with participants. Interview questions were formulated by the researcher on the basis of a literature review and document analysis of regulations, policies and acts on the management of ONIHL in the mining industry. The interview structure followed the recommendations of Rubin and Babbie [47], whereby the interviewer possesses a plan of inquiry as well as a set of questions. Furthermore, Kerlinger [20] also recommends that similar questions be grouped for cohesion and order. The interviews were conducted conversationally, and the questions were not asked in a specific order. The interview schedule took between 30 and 45 min to complete. Interviews were conducted in English, as this was the language of choice for all the participants. Broadly, the interviewer questions focused on the participants' occupational positions, their role and views on the formulation and implementation of the 2003 milestones/HCPs, as well as their opinions regarding factors affecting HCPs.

Ethical considerations

All procedures contributing to this work complied with the relevant standards of the national and institutional guidelines on the human subject for research purposes. Therefore, this study adhered to the Helsinki Declaration of 1975 as revised in 2008 [55]. Consequently, before commencing with the study, approval was obtained from the University's Human Research Ethics committee (Medical) (Protocol number: M160264) and a platinum mine in one of the provinces in South Africa. Furthermore, ethical aspects, such as confidentiality and the right to withdraw from the study were discussed with the

Table 1 List of participants and their occupational positions

Participant	Position	Group
1	Labour representative	Mine Health and Safety Council
2	Employer representative	Mine Health and Safety Council
3	State representative	Mine Health and Safety Council
4	Employer representative	Mine Health and Safety Council
5	Employer representative	Mine Health and Safety Council
6	Employer representative	Mine Health and Safety Council
7	Senior ventilation and occupational health engineer	Occupational health officer
8	Ventilation and occupational health engineer	Occupational health officer
9	Occupational hygiene assistant	Occupational health officer
10	Occupational audiologist	Private company affiliated with a mine
11	Occupational audiologist	Private company affiliated with a mine
12	Occupational audiologist	Employed by the mine
13	Occupational audiologist	Private contractor at a mine
14	Occupational audiologist	Private practice affiliated with a mine
15	Occupational audiologist	Private company affiliated with a mine
16	Occupational audiologist	Private contractor at a mine

participants. Anonymity, however, was not guaranteed, as snowball sampling was utilized in this study. Participants were made aware that all information given to the researcher would be kept confidential.

Data collection procedure

Initially, potential participants were contacted telephonically or via email to request their participation in the current study. In line with purposive snowball sampling, participants were only contacted when the referring person obtained permission from possible participants to forward their contact details to the researcher. The researcher contacted and asked them whether they were still willing to participate. Participants were furnished with relevant information such as the information letter and the consent forms. On the day of the interview, upon arrival at the set venue, the researcher introduced herself and again highlighted the aim of the interview, including ethical considerations. Participants were again provided with hard copies of the information letter and consent forms. Furthermore, they were given an opportunity to read and to ask questions if they had any questions. Participants were required to sign the consent forms to indicate that they were voluntarily agreeing to participate. With permission from all participants, interviews were audio-recorded for purposes of later analysis as well as to increase the accuracy of data collected and to allow the researcher to be fully attentive to the participants instead of handwriting verbatim transcripts during the interviews. With telephonic interviews, participants were emailed the information and consent letters. They were requested to return the consent form before undergoing the interview. These interviews were conducted via teleconferencing mode to audio-record them. As per the Human Research Ethics Committee regulations, data were stored in a password-protected laptop with the intention of destroying them after 5 years. Only the researchers, N.M. and K.K.S., had access to the data.

Data analysis

Inductive thematic analysis was employed to analyse the data, allowing for coding without imposing a pre-existing coding framework. This approach minimized the influence of the researchers' analytic preconceptions, enabling themes to emerge organically from the data [2]. The analysis adhered to the steps recommended by Braun and Clarke [2], including familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining themes and writing up the findings. NVivo software was utilized to systematically code and analyse the data, beginning with the importation of the data into the software. The familiarization phase involved a thorough review of the data, during which initial notes and observations were documented using NVivo's annotation features. Initial codes were then generated by highlighting relevant sections of the text and organizing them into descriptive nodes. NVivo's hierarchical node structure enabled efficient grouping of related codes into broader themes. The themes were then reviewed, refined, clearly defined and named, with detailed analyses supported by data excerpts retrieved from the coded nodes. During the write-up phase, these themes were integrated into a coherent narrative, with NVivo facilitating the extraction and inclusion of verbatim quotations to

support the study's findings. This process enhanced the rigour and depth of the analysis.

Trustworthiness

Reflexivity and bracketing were applied to guard against any bias from the researcher. A peer reviewer served as a mirror and assisted in reflecting on the researcher's responses to the interviews. Also, the current authors made use of the "community of practice" [46] to share the process and the findings of the study with a group of colleagues familiar with ONIHL and policies governing noise management in the mines. Furthermore, after transcribing the interviews, the researcher conducted member or participant checks to "learn from the interviewee how well the researcher's interpretations reflect the interviewee's meaning" [37]. Thereafter, following the transcription of interviews, the researcher contacted some participants for more clarification where clarity was required.

Results and discussion

The inductive thematic analysis used to analyse results revealed the following themes: crisis management; some are more equal than others; cost of an individual's hearing; we have tried, but then reality intervenes; knowledge is power; and show and tell. These themes are discussed and supported by quotations below.

Theme 1: Crisis management

Participants were asked to share their perspectives on the objectives and expected outcomes of the implemented milestones for managing ONIHL. Their reflections reveal significant dissatisfaction with the process, highlighting several critical issues. Many participants expressed frustration over the lack of clearly defined action plans, which they felt undermined the effectiveness of the milestones. They also voiced concerns about inadequate collaboration and accountability among stakeholders, which further hindered the successful implementation of the initiatives.

Participant (P) 5 shared the following:

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

P10 revealed that:

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

P7 described the 2003 ONIHL milestones as:

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

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

P2 lamented the lack of buy-in:

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

P4 added that:

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

P6 elaborated:

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

Theme 2: Some are more equal than others

Given their training and scope of practice, audiologists are crucial in decision-making regarding the managing occupational noise. In this study, participants were asked specifically about the role of audiologists and their involvement in the formulation and implementation of the 2003 MHSC milestones. The audiologists expressed frustration at being excluded from all stages of these processes despite being tasked with executing

certain functions. Meanwhile, other stakeholders perceived audiologists as less central to decision-making and more relevant to operational aspects. In fact, audiologists felt that other stakeholders were prioritized over them in these discussions. This exclusion highlights a notable disconnect between their marginalization in strategic discussions and the responsibilities expected of them in managing ONIHL in occupational settings. In this regard, P12 stated:

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

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

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

P13 mentioned specific roles directly linked to audiologists' role in the management of ONIHL.

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

Interestingly, when non-audiologist participants were asked about their opinions on the involvement of audiologists in the decision-making process, the responses varied from acknowledging the importance of the inclusion of audiologists to employing their services on a need-to-basis and not needing them at all. For instance, P2 stated that:

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

P3 explained that:

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

P5 summarized the role of audiologists in this manner:

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

P2 elaborated on the role of audiologist in the formation of 2014 milestones:

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

Theme 3: Cost of an individual's hearing

In light of recent trends towards the buying quiet approach, participants were asked to reflect on the role of engineering controls and their effectiveness in mitigating or eliminating new cases of occupational noise-induced hearing loss (ONIHL). Most participants agreed that investing in engineering controls, specifically through the buying quiet strategy, could significantly reduce and

potentially eliminate new instances of ONIHL in the mining industry. P9 declared that:

"On top of the list is 'buying quiet'".

P1 recalled that:

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

P14 elaborated further:

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

While participants reported a shift toward buying quiet, some participants also cited concerns regarding the costs of buying quieter equipment. However, there were responses to this argument.

P2 shared the following:

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

Additionally, P1 lamented:

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

Theme 4: We have tried, but then reality intervenes

Participants were asked to reflect on the challenges associated with the buying quiet strategy and other initiatives aimed at improving occupational health and safety in the mining sector. Interestingly, their responses revealed unintended consequences despite the industry's efforts to prioritize noise reduction. A key issue identified was that, while the buying quiet strategy sought to lower noise levels and improve safety, it inadvertently encouraged some workers to expose themselves to higher noise levels. For example, there were instances where workers removed silencers from machines. This behaviour was largely driven by compensation pay-outs related to ONIHL. Motivated by the potential financial gain, some workers chose to remain in noisy environments rather than taking preventive measures to protect their hearing.

Participant 7 shared:

"I definitely think that compensation plays a very big role. I definitely think that it plays a very big role because unfortunately we see a lot of people who pretend to have a hearing loss because they want compensation. It is something that in a very sad way motivates them not to look after their ears because they think they gonna (sic) get money."

P6 added:

"...You know because there are production bonuses in the industry. Sometimes people feel... people then sacrifice health and safety because they are chasing production bonuses."

These sentiments were also shared by P2:

"When we intervene, then the exposed individual says 'I can hear' because there are incentives for high production and you know so and so is strong. That same individual will go back to drilling because he knows that his team depends on him. So there are those dynamics."

The sentiments from P2 also highlight the challenges with implementing administrative controls where workers can be moved around to protect them from occupational noise. This participant further elaborated:

"So then the discussion shifted to should there not be indicators of health and safety that are included in the bonus. So, you know, sort of be remunerated or rewarded for high production but also at the same time keeping or maintaining health and safety."

Theme 5: Knowledge is power

To gain insights into the impact of awareness campaigns and training initiatives on ONIHL, participants were asked to reflect on how awareness campaign efforts have influenced the attitudes and practices of both employers and employees. Specifically, they were questioned about the effectiveness of various campaigns in shifting mindsets, improving understanding and promoting better practices related to noise exposure in the workplace. This inquiry aimed to uncover the tangible outcomes of such

initiatives and to assess whether they have led to meaningful changes in how noise hazards are managed and perceived within the mining industry. P5 expressed that:

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

P10 indicated.

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

Meanwhile, P4 said:

> *"We also have campaigns. We've collaborated with hygiene (practitioners) on medical campaigns. If we have a TB Day, you invite the noise clipper guys for on-going awareness. When we have your HIV Day, your health days, we rope in hygiene as well. So, it's on-going via medical surveillance. It's on-going during campaigns".*

One participant mentioned the need to perhaps have a campaign that solely focuses on noise exposure.

> *"To be honest, we haven't done a campaign solely on noise and I think this year, depending on funding we will look into such a campaign." (P1)*

Theme 6: Show and tell

Participants were asked to reflect on any achievements or successes in the implementation of the milestones. A theme that emerged from the results was that of the use of "Leading Practice" as a way of encouraging all the stakeholders to develop initiatives that will assist in the elimination of ONIHL in the mining sector. This was a response in the realization that certain mines or companies were developing excellent and effective initiatives; however, they were not sharing them with other mines.

P14 expresses this well:

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

P12 elaborated further:

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

P1 supports this here:

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

Discussion

The Mine Health and Safety Council's milestones were initially conceived before their implementation in 2003. The stakeholders involved in conceptualizing these milestones may not have been directly involved in their implementation and monitoring. This is a typical journey of complex interventions, starting with policy and transitioning to practitioners before reaching the intended end-users [43]. In this current study, most of the stakeholders were involved in the implementation phase. Harris et al. [17] recommend that stakeholders should

preferably be involved from inception to the completion of the process. Due to the complexity and the long timelines from formulation to implementation and monitoring and evaluation, stakeholders may leave their posts, and others may be co-opted as and when their skills are needed. While it is understandable why the stakeholders interviewed in this study were not involved in the formulation of the milestones, it is important to note that the success of HCPs relies heavily on the knowledge and involvement of policy-makers and stakeholders throughout the entire process [11].

Knowledge plays a crucial role in the effectiveness and success of any organization or intervention. The quality and quantity of knowledge available, as well as the ability to share that knowledge, are essential for organizational processes and performance outcomes [56]. Ideally, stakeholders involved in conceptualizing milestones should have shared institutional knowledge about the goals, processes and expected outcomes. However, the study revealed that some stakeholders joined the implementation journey without clear action plans, which were only developed in 2008.

HCPs are complex interventions that require well-defined goals, theories and the involvement of all stakeholders with sound knowledge [34, 35]. Addressing administrative issues, such as clarifying company action plans, regulations and policies and identifying and enforcing individual responsibilities and roles, is a critical step in implementing a health program [14]. The absence of action plans may have contributed to the lack of collaboration and buy-in from all stakeholders in HCPs. Meaningful engagement and buy-in from stakeholders and implementers are crucial for successful implementation of evidence-based interventions [18]. Lack of buy-in can hinder progress or compromise the effectiveness of the intervention. It is important to note that the absence of buy-in may result in interventions not being implemented at all [18]. While the milestones were implemented, the lack of buy-in from stakeholders significantly compromised the success of the milestones implemented in this study. Similar observations were made in a study evaluating the effectiveness of HCPs at 13 manufacturing plants in the USA. This study identified gaps in HCP implementation and highlighted that management commitment and worker counselling on ONIHL are critical to the success of these programmes [45]. This highlights the necessity of stakeholder engagement and demonstrates that challenges with HCP implementation are not confined to South Africa or the mining industry alone, as similar issues were found in the American context in a manufacturing setting. Conversely, other research indicates that clear objectives and strong stakeholder support can lead to positive outcomes. For instance, a longitudinal case study conducted at a metallurgical plant in Brazil from 2003 to 2018 showed that the implemented HCP had a favourable impact, effectively reducing cases of ONIHL over the study period [26].

Particularly, the exclusion of key stakeholders, such as audiologists, had a negative impact on the success of the Mine Health and Safety Council (MHSC) milestones. Moroe et al. [29] conducted a study on the role of audiologists in managing occupational noise in the mining sector. The following themes emerged: scope–context misalignment, juniorization of experts, uncertainty about the importance of audiologists and limited training in occupational audiology. Audiologists play a crucial role in advising on the auditory and non-auditory effects of noise on the health and well-being of exposed individuals, as well as the impact of noise on communication and job permanence [33, 36]. Furthermore, involving audiologists is essential for advising stakeholders, particularly the mining industry, on the operational aspects of hearing conservation programs (HCPs), including management responsibilities and liabilities under occupational health and safety regulations and Workers' Compensation statutes. Occupational audiologists can also recommend the most effective and cost-efficient methods for implementing each component of the HCP, considering the advantages and disadvantages of in-house resources versus external service providers. Moreover, they can contribute to forensic activities such as serving as expert witnesses in hearing loss compensation claims and other litigation cases [33, 36].

Occupational audiologists bring valuable expertise to the table when it comes to implementing HCPs, as they have the knowledge to recommend the most successful and cost–effective approaches for each component of the program. This includes considering the advantages and disadvantages of developing in-house resources versus outsourcing to external service providers. By leveraging their expertise, HCPs can be optimized to achieve the best outcomes for worker health and safety [33, 36]. Lastly, occupational audiologists are involved in forensic activities related to hearing loss compensation claims and other forms of litigation, such as product liability cases. Their involvement in these activities underscores their role as experts in the field and highlights their ability to provide valuable insights and support in legal proceedings. In this current study, the input from audiologists shaped the 2014 milestones from using the percentage loss of hearing (PLH) to standard threshold shift (STS). This suggests that audiologists should have been consulted during the initial formulation of the 2003 milestones. A study by Mutara and Mutanana [39] analysing a HCP at a mining company in Zimbabwe emphasized the need for the company to employ a full-time audiologist

on-site to ensure that employees with hearing issues receive timely assistance. Managing ONIHL falls within the scope of practice for audiologists. The American Academy of Audiology recognizes audiologists as the principal advocates and supervisors of Health Conservation Programmes [48]. Therefore, excluding audiologists from the process raises concerns about prioritizing cost over worker health and well-being. While mines may prefer audiometrists due to their lower cost, it is important to consider the value of an individual's hearing and the potential consequences of not involving audiologists.

There is a strong commitment by the mining industry to eliminate occupational noise-induced hearing loss (ONIHL) and emphasize their recognition of the importance of employee well-being. This commitment is demonstrated through their investment in engineering controls, commonly referred to as buying quiet. Engineering controls are considered the primary defence against exposure to loud noise, and if effectively implemented, they can eliminate the need for other control measures such as personal hearing protection devices [52]. Implementing engineering controls can have significant benefits for both the mining industry and its employees. Firstly, it can lead to the elimination of disability for employees, ensuring their long-term health and well-being. Additionally, the costs associated with regular hearing monitoring and compensation related to hearing loss may be completely eliminated. Bruce [4] supports these benefits by highlighting advantages such as permanence, effectiveness regardless of worker compliance, reduced absenteeism, improved communication, lower worker compensation costs and decreased legal expenses. Although there are concerns that buying quiet can be challenging and costly, adopting a perspective where this is viewed as a long-term investment may outweigh the perceived costs. The principle of buying quiet is not exclusive to South Africa; it is also reflected in European regulations, such as the Machinery Directive 2006/42/EC. This directive requires manufacturers to reduce noise risks and provide comprehensive noise information, allowing employers to implement appropriate controls and compare machinery on the basis of noise levels [3]. While the current study supports buying quiet, it acknowledges concerns about the associated costs. Nonetheless, viewing these investments as long-term benefits for employee well-being can make buying quiet a viable strategy for mitigating ONIHL. The fact that all study participants strongly supported the concept of buying quiet indicates a united stand within the South African mining industry to preserve the hearing health of their employees. This collective commitment is an encouraging step towards the ultimate goal of eradicating ONIHL in mining operations.

HCPs as complex interventions are fragile, in that they can be vulnerable or sensitive to various factors that may impact their effectiveness. In this case, monetary incentives in the form of compensation pay-outs and production bonuses seem to have inadvertently led to unintended consequences in the success of the HCPs. Monetary incentives have traditionally been employed to motivate behaviour change and encourage healthier lifestyles [5, 53]. However, motivating behaviour change is a multifaceted process that can yield both intended positive outcomes and unintended negative consequences [53]. In this study, it was observed that production bonuses had counterintuitive effects on promoting positive behaviour change. Rather than fostering desired outcomes, the focus on monetary rewards seemed to compromise the intended goals of the HCPs. Reportedly, workers are more concerned about financial gain and, as a result, expose themselves to hazardous occupational noise. It is even more concerning that some workers intentionally exposed themselves to occupational noise for the purpose of seeking compensation. This underscores the importance of including all stakeholders, particularly the end-users, in the development and implementation of interventions and health promotion campaigns. Engaging end-users and stakeholders in the co-creation process is an effective strategy for achieving positive societal changes [23]. However, it is crucial to ensure that such campaigns are tailored to the specific needs and circumstances of the end-users. A study by Edwards et al. [10] highlighted the lack of a solid theoretical foundation of these health promotion campaigns and challenges with the language used in awareness training programs. The authors expressed concerns that the same material used to educate management about noise and its effects was also used to train the end-users. According to Leask et al. [23], this one-size-fits-all approach does not yield the desired outcomes. Instead, a more tailored approach that considers the individual needs and circumstances of the end-users should be developed in collaboration with them [23]. Overcoming language barriers is an important aspect to consider, as information should be presented in a manner that matches the workers' levels of understanding, enhancing learning and awareness while taking into account literacy, cultural and linguistic relevance [57]. As such, the complexity of HCPs requires careful consideration of various factors, including the impact of monetary incentives, tailoring interventions to the needs of end-users and addressing language and cultural barriers to ensure effective communication and positive behaviour change.

Lastly, complex interventions are not isolated entities; they are often leaky and susceptible to borrowing and benefit from cross-fertilization [34, 35].

Cross-fertilization refers to the process by which disciplines and stakeholders learn from one another to address complex and evolving empirical realities. It plays a crucial role in fostering scientific breakthroughs, generating innovative ideas and facilitating the integration of new knowledge through the sharing of concepts, ideas and empirical evidence among stakeholders [7]. In the context of this study, the development of excellent and effective initiatives that contribute to "leading practice" was reported. Leading practice involves identifying, implementing and disseminating the best innovations in health and safety by encouraging the mining industry to learn from pockets of excellence that exist within the sector [50]. By working collectively and avoiding working in isolated silos, cross-fertilization of ideas can occur, as different mines share strategies that have proven effective in their specific contexts. It is important to recognize that not all ideas or strategies may work universally for all mines, as the characteristics and challenges may vary between small-scale and large-scale mining operations, for example. However, the process of cross-fertilization allows for transparent and meaningful knowledge exchange, enabling informed decisions to be made regarding the improvement of occupational health and safety in the workplace. By learning from one another, stakeholders can benefit from shared experiences, insights and innovative approaches, ultimately driving continuous improvement in health and safety practices. As such, the leakiness of complex interventions presents an opportunity for cross-fertilization, which enables stakeholders to learn from each other and address the complexities and evolving realities of their respective fields. By fostering collaboration and knowledge exchange, meaningful progress can be made in improving occupational health and safety outcomes within the mining industry and beyond.

Conclusions

This study reveals that the management of ONIHL through HCPs in the South African mining sector is highly complex and requires a multifaceted approach. Key factors contributing to both the success and failure of HCPs were identified, including stakeholder collaboration, the inclusion of audiologists and end-users and the systematic application of best practices. A significant gap noted is the frequent omission of employees as stakeholders in these programmes, which undermines their effectiveness and acceptance.

Implications for policy and practice

- **Complex interventions:** HCPs should be recognized and treated as complex interventions requiring comprehensive planning, clear objectives and desired outcomes. This approach will help address the multifaceted nature of ONIHL management and improve the likelihood of successful implementation.
- **Stakeholder inclusion:** For HCPs to be effective, it is critical to include all stakeholders, particularly employees, who are the primary beneficiaries. Empowering employees through education and active participation in noise management can lead to better adherence to safety practices and a reduction in noise exposure.
- **Collaboration and buy-in:** Collaboration among all stakeholders, including mining companies, policy-makers, audiologists and workers, is crucial. Without this collective effort, HCPs risk being neglected, resisted or even sabotaged, undermining their effectiveness.
- **Adoption of best practices:** The mining sector should maintain leading practices, such as buying-quiet initiatives and effective awareness campaigns, to minimize noise exposure at the source. These strategies can significantly reduce the incidence of ONIHL and improve overall occupational health.
- **Policy integration:** Policy-makers should integrate these findings into regulatory frameworks, ensuring that HCPs are not only mandated but also adequately supported and monitored. This integration is vital for creating a sustainable and effective approach to managing ONIHL in the mining industry.

Recommendations

To effectively address ONIHL in the South African mining industry, a set of targeted strategies is proposed to enhance HCP success. By fostering collaboration, setting clear objectives and integrating HCPs into broader occupational health strategies, these recommendations aim to create a sustainable approach to noise management. The proposed actions focus on making HCPs effective, comprehensive and continuously improving, with the goal of significantly reducing ONIHL and enhancing workers' health and well-being. These strategies include:

- **Inclusive stakeholder engagement and collaboration framework**: Conduct a comprehensive stakeholder identification and mapping process to ensure the inclusion of all relevant parties, including non-traditional stakeholders such as audiologists, who have expertise or interest in occupational health and safety and end-users who have the first-hand experience of using HCPs.
- **Collaborative approach:** (i) Form cross-sector working groups including mining companies, unions,

audiologists and policy-makers to share knowledge and discuss ONIHL strategies. (ii) Create centralized online knowledge hub/platform for stakeholders to access and contribute resources, maintained by a neutral body such as the Chamber of Mines.

- **Clear objectives and planning:** (i) Develop and disseminate standardized goals for HCPs tailored to different mining operations. (ii) Hold annual workshops for HCP managers to align objectives and timelines with best practices and regulations.
- **Comprehensive strategy:** (i) Ensure HCPs are part of broader occupational health and safety strategies with regular updates. (ii) Work with regulatory bodies to set and enforce standards for noise exposure and hearing conservation.
- **The buying quiet approach:** (i) Provide tax incentives for investments in noise-reducing technologies. (ii) Implement procurement guidelines prioritizing quieter equipment for new purchases.
- **Effective awareness campaigns:** (i) Design campaigns taking into consideration the diverse backgrounds of the workforce, using multimedia to communicate risks and the importance of protection.
- **Inclusion of audiologists: (i)** Include and formalize roles for audiologists in HCP design and evaluation through industry regulations. (ii) Create audiology advisory panels for ongoing input and refinement of HCPs.
- **Complex intervention perspectives:** (i) Train HCP managers in systems thinking to manage the complexities of HCPs. (ii) Test multi-level interventions addressing individual, organizational and community factors.
- **Continuous improvement:** (i) Implement real-time noise monitoring systems to adjust practices and equipment. (ii) Conduct regular mandatory third-party audits of HCPs to ensure effectiveness and improvement.

Limitations

The findings of the study are context-specific; therefore, they cannot be generalized to other contexts due to the following considerations:

Context-specific nature: The study focused on a specific industry – mining in South Africa – where unique regulatory, environmental and operational factors are at play. The views and experiences of stakeholders in this sector may not be applicable to other industries, even within South Africa. For instance, the challenges faced in implementing HCPs in mining may differ significantly from those in other sectors such as manufacturing or construction, limiting the direct transferability of the findings.

Small and specific sample size: The study's sample size of 16 participants, although sufficient for in-depth qualitative analysis, is relatively small and highly specific, including representatives from the state, labour, employers, audiologists, engineers and occupational health practitioners. The purposive sampling strategy, while effective in selecting individuals with relevant experience, does not allow for the generalization of findings to the broader population of stakeholders in the mining industry or other sectors.

Temporal context: The study was conducted within a specific timeframe and within the context of existing policies, regulations and milestones related to ONIHL in the South African mining industry. Changes in these external factors over time, such as updates to legislation or shifts in industry practices, could affect the relevance of the findings to future contexts. Therefore, the findings may have limited applicability outside of the specific period in which the study was conducted.

Future studies

- Conduct a detailed economic analysis to assess the cost–effectiveness and financial implications of various HCP strategies. This should include cost–benefit evaluations of engineering controls versus personal hearing protection devices, providing policy-makers with insights into the return on investment and overall financial impact.
- Undertake longitudinal studies to explore the long-term outcomes of HCPs. Evaluating the sustained effectiveness and sustainability of these programmes over extended periods will help determine their impact on reducing ONIHL and guide future improvements in program design.
- Examine the efficacy of specific interventions within HCPs. Research should focus on identifying which particular strategies or components, such as different types of engineering controls, training programs or personal protective equipment, are most effective in reducing ONIHL. This will aid in refining and optimizing HCPs for better results.
- Develop and test models for more inclusive stakeholder engagement in HCP formulation and implementation. This research should explore methods for involving key stakeholders, such as audiologists and workers, from the early stages to ensure comprehensive collaboration and buy-in.
- Investigate end-user perspectives on HCPs to understand workers' attitudes, behaviours, and compliance. Gathering feedback from workers can help tailor

interventions to better meet their needs and improve the overall effectiveness of HCPs.

Author contributions
NM conceptualised the manuscript, collected and analysed the data, and wrote the manuscript. KKS supervised the study, reviewed the data, and approved the final draft.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical clearance was obtained from the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg, South Africa (Protocol Number: M160264). Participants gave written consent after reading and understanding the participants' information sheet. All identifying information was removed in the presentation of the findings.

Consent for publication
Participants consented, as this information was included in the information sheet.

Competing interests
The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

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