A HANDBOOK ON

OCCUPATIONAL HEALTH PRACTICE
IN THE SOUTH AFRICAN MINING INDUSTRY

CHAPTER 10

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Chapter 10

Noise and Vibration

This chapter covers best practice regarding the hazards of noise and vibration. It is intended as a practical guide and reference document, as well as a tool for audits/assessments and prioritising sources of risk for appropriate interventions. The chapter also serves as an informational and educational tool for persons unfamiliar with these two important health hazards. The appendices facilitate access to more specific details.

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10.1 Introduction

Sound and vibration both originate in the mechanical movement or excitation of machinery, its sub-assemblies, and components. Movement or excitation of these objects causes their repetitive displacement and, thus, the transmission of energy into surrounding air or structures. If the level of energy is sufficient to excite a structure or the ground, and the frequency of propagation is relatively low (generally below 20 Hz), then the result is *vibration* perceptible through the tactile sense (touch). When the energy is directly or indirectly transmitted to the surrounding air at a propagation frequency of 20–20 000 Hz, it is perceptible via the hearing sense as *sound*. Sound is regarded as *noise* if it has the potential to interfere with communication or damage people's hearing.

Both noise and vibration pose significant risks to workers' health, safety, and productivity. While these hazards share some characteristics, their health effects and control measures differ. This chapter addresses each hazard separately, providing targeted guidance for effective risk management.

10.2 Noise: Health Effects and Controls

10.2.1 Extent of problem

Noise has been increasingly recognised as a significant health hazard for workers and a serious financial threat to many industries. The data extracted from the Department of Minerals and Petroleum Resources (DMPR) annual reports showed that around 73.2% of mineworkers were exposed to noise levels more than the legislative value of 85 A-weighted decibels (dBA) in the South African mining industry (SAMI) in 2020, (1). The data further show that noise-induced hearing loss (NIHL) is one of the commonly reported occupational diseases (1).

Predominantly, the sources of noise in the SAMI include:

- Equipment and machinery such as excavators, stage loaders, shearers, compressors, fans, and continuous miners
- Drilling, blasting, and transportation of rock and materials
- Underground mining conditions, with confined spaces and moving headings

Typically, the occupations most exposed to noise in the SAMI are summarised in **Table 10.1**, which is the population most at risk of developing NIHL according to a review study by Khoza-Shangase, Ntlhakana, and Nelson (2).

Table 10.1. Occupations most at risk of developing noise-induced hearing loss

Occupation	Mean exposure level (LAEq) dBA
Drillers	105.5
Loco drivers	95.3
Development team members	93.2
Multi-task workers	92.3
Winch operators	92.1

LAeq: A-weighted Equivalent Continuous Sound Level

Source: Adapted from Khoza-Shangase et al. (2020) (2)

10.2.2 Noise control interventions in the South African mining industry

Over the last two decades, the SAMI has implemented a number of noise control mechanisms, mainly focused on preventing hearing loss and complying with Regulations like the Mine Health and Safety Act No. 29 of 1996 (MHSA) (3) and the Occupational Health and Safety Act No. 85 of 1993 (OHSA) (4). The methods used to control noise have included engineering controls, such as enclosing noisy equipment and implementing absorption and insulation techniques, administrative controls, such as altering work schedules to reduce exposure, implementing personal protective equipment (PPE) like earplugs, and providing education, training and awareness programmes.

10.2.2.1 Hearing conservation programmes

The SAMI introduced hearing conservation programmes (HCPs) in the late 1980s and later formalised them in 2003 through the Mine Health and Safety Council (MHSC) (5). Hearing conservation programmes subsequently became compulsory, since labour-intensive methods, common to many mineral extraction and processing operations, were resulting in large numbers of people being routinely exposed to noise beyond the legally recognised safe limit of 85 dBA (5).

The main aim of the HCP is to prevent NIHL by implementing various measures such as noise monitoring, engineering controls, administrative controls, personal hearing protection, employee education, audiometric evaluations, and data management of noise measurements.

10.2.2.2 Guidance notes for noise reduction

In 2003, the Department of Minerals and Petroleum Resources (DMPR) issued a guidance note for the compilation of a mandatory Code of Practice (CoP) for an occupational health programme (occupational hygiene and medical surveillance) for noise – DME 16/3/2/4-A3 (6). This was in recognition of the provisions of the section 11 of the MHSA, which requires that the employer should identify hazards, assess the health and safety risks to which employees may be exposed while they are at work, and record the significant hazards identified and risk assessed.

Where the employer’s risk assessment indicates a need to establish and maintain a control system for noise, this guideline addresses the assessment and control procedures, aspects of personal exposure monitoring, education and awareness training, hierarchy of controls, noise medical surveillance, reporting, and review.

10.2.2.3 Guidance notes for standard threshold shifts (STS) of noise-induced hearing loss

Another guidance note was issued in 2016 by the DMPR to provide a framework for implementing the STS principles in the mine’s medical surveillance system – DMR 16/3/2/3-B8 (7). Audiometric testing forms an integral part of the medical surveillance system, and monitors the employee's hearing sensitivity and deterioration over time, whilst simultaneously providing an opportunity for employers to educate employees about their hearing and the need to protect it.

The guidance note states that the milestone baseline standard should be the average hearing level calculated using 2 000 Hz, 3 000 Hz, and 4 000 Hz to obtain standard thresholds per ear. Follow-up audiometric tests should then be compared with the milestone baseline standard thresholds to determine the standard threshold shift (STS). An STS is an average change in hearing of 10 dB or more at 2 000 HZ, 3 000 Hz, and 4 000 Hz from baseline, in one or both ears.

When a standard threshold shift greater than 10 dB is identified, two actions are required. First, the employee must be flagged for follow up, and the mine must initiate an investigation into the effectiveness of the Hearing Conservation Programme. Second, if the audiogram indicates a hearing loss exceeding 25 dB from audiometric zero, the case becomes reportable in accordance with applicable regulatory requirements.

10.2.2.4 Guidance notes for ground vibrations, noise, air-blast, and flyrock

More recently, in 2024, the DMPR issued a guideline for a mandatory code of practice for minimum standards on ground vibrations, noise, air-blast, and flyrock near surface structures and communities – DMRE 16/3/2/1-A8 (8). This guideline was issued to clarify the standards around ground vibrations, noise, and air-blast in the absence of a local guideline in the SAMI, which relied on United States Bureau of Mines (USBM) standard to assess whether ground vibrations exceed safe limits.

The main aspects in this guideline include the management of risks and hazards on ground vibration, noise, air-blast, and flyrock incidents emanating from blasting practices at mines, including the standard operating procedures (SOPs). Some of the SOPs include pre-surveys to identify all relevant structures to be protected, drill and blast designs, quality assurance and control, monitoring and recording, or accrual blast results, and management of complaints.

10.2.2.5 Mine Health and Safety Council 2024 milestones for elimination of noise-induced hearing loss

As indicated in Chapter 1 of this Handbook, the MHSC holds occupational health and safety (OHS) summits periodically, to revise and reprioritise OHS delivery milestones for continuous health and safety improvement. At the 2024 MHSC OHS summit, the main target set for delivery by the end of 2034 is to eliminate NIHL through quietening of equipment. This is to be achieved as follows (9):

- *"By December 2034, the noise emitted by individual pieces of equipment operated by employees and individual process equipment should not exceed a milestone sound pressure level of 104 dBA."*

- *"Using current diagnostic methods, by December 2034, there should be no novice cases of noise induced hearing loss amongst previously unexposed individuals. ("Previously unexposed individual" are those unexposed to occupational noise prior to December 2024 i.e. Equivalent to a new person who entered the industry in January 2025.)"*

Based on these milestones, the Mining Industry Occupational Safety and Health (MOSH) have issued actionable strategies designed to support the effective implementation of the new OHS milestones. These include using acoustic engineering in designing or re-designing workplaces to minimise noise risks, systematically managing residual noise risk from equipment, fostering strategic partnerships with original equipment manufacturers (OEMs) and driving the identification and adoption of leading practices and research outcomes (10).

10.2.2.6 The Mining Industry Occupational Safety and Health guidelines

The MOSH, in partnership with the Minerals Council South Africa (MCSA) and the MHSC centres of excellence, continue to implement leading practices from the OHS learnings over time, and have issued further guidance on the implementation of certain aspects of noise control.

- **Guidance note for the implementation of the Industry-Wide Buy and Maintain Quiet Initiative (IBMQI)** (11)

  Equipment noise emissions are a significant OHS risk within the SAMI. To effectively manage the noise hazard, it was necessary to develop a practical and effective IBMQI aimed at assisting the industry in their efforts to eliminate and/or control noise at the source. Noise emission of equipment forms the key focus of the IBMQI, with the appropriate application of incorporating noise as a parameter when procuring and maintaining any equipment used in the industry.

This guidance note provides guidance on the process to be applied when procuring new equipment, including the repair and maintenance requirements to ensure that noise levels emitted by equipment used in the industry meet the noise industry milestones.

- **Guidance note for the implementation of a quality assurance plan** (12)

This guidance note was developed to assist industry members in ensuring that all items of sound measuring equipment used are calibrated against the requirements of IEC 60942, SANS 61672, and SANS 61672-2 (by an accredited facility), by recommending and specifying certain sets of tests for the periodic testing of sound level meters and accompanying instruments.

Sound pressure level meters are used to classify and quantify the nature, magnitude, and origin of noise and sound sources. Sound level meters, sound level calibrators (SLCs), fractional octave band filters, and personal sound exposure meters (PSEMs) are all manufactured according to the International Electrotechnical Commission (IEC) standards. This guidance note ensures that uniformity is maintained across all measurements.

10.2.3 Legal responsibilities of employers and workers

In terms of the MHSA, employers' obligations, specific to noise, are:
- Risk assessment, noise control engineering, noise monitoring, and medical surveillance
- Hearing and safety training for noise-exposed persons to reduce the risk of NIHL
- Provision of appropriate hearing protection devices (HPDs) to noise-exposed persons
- Compilation of a CoP for controlling noise and managing the risk of NIHL

Workers' obligations, specific to the noise hazard, are:
- The proper use and care of HPDs
- Reporting problems that may preclude or limit their use of HPDs
- Reporting noise sources, communication problems, or perceived lack of protection

In terms of section 43 of the OHSA, the DEL made provisions of employment regarding the NIHL Regulations, gazetted as No. 7121 (13).

Section 10 of the NIHL Regulation provides that an employer or self-employed person shall ensure that the exposure of a person to noise is either prevented or, where this is not reasonably practicable, adequately controlled. The control of the exposure shall be regarded as adequate if, a) the exposure is below the noise-rating limit, or b) the exposure is at, or above, the noise-rating limit, but the reason has been identified and action is taken as soon as is reasonably practicable, by means other than the use of hearing protective equipment, to lower exposure so that it does not exceed the noise-rating limit.

The Regulation further provides that the employer or self-employed person should implement noise control measures, such as engineering control measures to eliminate or reduce noise at its source, or the modification of the routes by which noise reaches workplaces; administrative control measures to limit the number of persons exposed and the duration of exposure; and the use of hearing protective equipment if engineering and administrative control measures fail to reduce exposure below the noise-rating limit.

The duties of the persons who may be exposed to noise are outlined in section 5 of the NIHL Regulations, providing that such person shall obey any lawful order given to them by the employer or self-employed. Such orders may include use of measures adopted for noise control, reporting of defective, damaged, or lost noise control equipment to the health and safety representative (HSR) or the employer, and the use of personal hearing protectors provided.

In cases where risk control measures ultimately fail to prevent NIHL, affected persons may be eligible for compensation. In terms of the Compensation for Occupational Injuries and Diseases Act No. 130 of 1993 (COIDA), the employer is obliged to report such cases to the Compensation Commissioner or to the relevant mutual association, even if in dispute of their merit (section 68) (14).

In 2001, the Compensation Commissioner issued Circular Instruction No. 171 to determine permanent disablement resulting from NIHL and trauma (15). The instruction outlines procedures for assessing and calculating permanent disability due to hearing impairment, including guidelines for binaural and monaural hearing losses, and the documentation required for compensation claims.

10.2.4 Quantifying noise and exposure levels for risk assessment and occupational hygiene monitoring

Although details of the physical properties of noise and relevant measurement techniques are beyond the scope of this Handbook, basic concepts are included. These include sound pressure level meters and the decibel (dB). Sound pressure meters, sound power/sound power level, and various parameters for quantifying noise exposure are beyond the scope of this Handbook, and should be explored by consulting other sources, including some of those listed as references.

It is important to note that every 3-dB increase in the level of workplace noise beyond the 85 dB limit, requires a 50% reduction in exposure time for unprotected workers, to adhere to the legal limit. For example, unprotected exposure to an equivalent continuous noise level of 88 dB would be permissible for < 4 hours per day, or for < 2 hours per day in the case of a level of 91 dB.

10.2.4.1 Sound pressure

Sound can be propagated in any medium such as air, water, or solids, but ultimately reaches the ear via the air. Most measurement parameters are based on the variations in air pressure that sound produces. The human ear is sensitive to a broad range of sound pressures and responds to pressure differences in a logarithmic rather than a linear manner. This makes a logarithmic scale useful for characterising the 'loudness' (magnitude or intensity) of sound. Sound is normally quantified on the logarithmic decibel scale, relative to the normal ear's threshold of hearing of 20 micro pascals (μPa) at 1 000 Hz. As the threshold for normal hearing, 20 μPa has been adopted as the reference level for sound pressure and is assigned a value of 0 dB. The 20 -Pa (20 000 000 μPa) threshold of pain for normal ears has a value of 120 dB.

10.2.4.2 Exposure level

Workers' exposure to noise can be quantified by means of several parameters, but regulatory requirements and practical considerations generally determine the parameter of choice. South African National Standards (SANS) 10083:2023 stipulates an A-weighted Rating Level over time period T (LAr,T) as the basis for determining exposure level (16). The $L_{Ar,T}$ is derived from sound level meter (SLM) measurements, which impose practical difficulties for assessing risk.

When the noise level varies during the working day, SLM-based measurements require the observer to 'shadow' workers, and either manually integrate results or use an integrating instrument to combine results from multiple measurement intervals. This reduces the number of samples that can be obtained from SLM-based monitoring and may also affect the representativeness of results if the observer elects to sample for less than a full shift (8 hours).

Reasons for stipulating the use of $L_{Ar,T}$ mainly relate to the SANS 10083:2023 requirement for Type-1 and

Type-2 instrument precision (typically ± 0.7 dB). Personal noise dosimeters, which quantify personal noise exposure, normally provide only Type-2 accuracy (typically ± 1.0 dB). Instrument precision for noise dosimeters is determined in accordance with SANS 61672-1:2023 Ed 2, SANS 61672-3:2023 Ed 2, and SANS 61672-14:2023 Ed 2 for integrating SLMs (17). In practice, the intrinsic variability of noise in the workplace (commonly ± 2 dB or more) makes the number of samples obtained and validity of the sampling strategy the most crucial factors in accurately quantifying workers' exposure and risk. Acceptance of Type-2 precision would allow the deployment of more (less costly) instruments and, hence, the accumulation of a greater number of samples to better inform the risk assessment process.

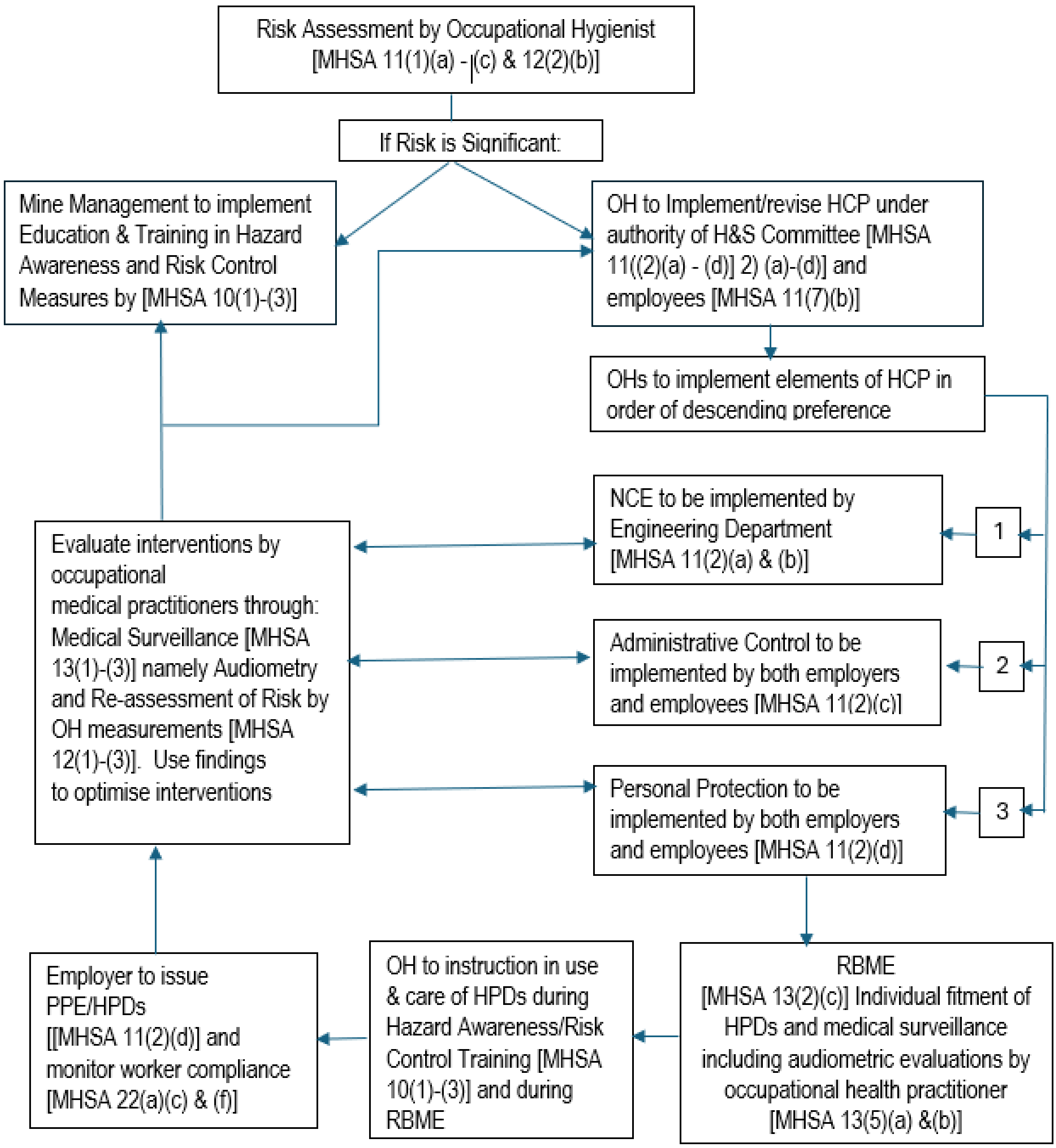
The potential for personal noise dosimetry to facilitate larger sample sizes, enabling the application of a rational sampling strategy, makes it the preferred method of exposure assessment (SANS 10083:2023). Furthermore, dosimetry is particularly useful when workers do not have fixed workstations, or they are subjected to significant sources of exposure outside their normal workplaces.

The mining industry should regard noise exposure level normalised to a nominal 8-hour working day (LEX, 8h), and time-weighted average (TWA) 8-hour equivalent noise exposure (Leq), as the preferred parameters for quantifying exposure, for both risk assessment and occupational hygiene monitoring purposes. These two parameters, measured in decibels by means of personal dosimetry, can be regarded as numerically equivalent. Only when significant exposure is confined to continuous and unvarying noise at fixed workstations, can SLM-based measurements readily provide a representative quantification of exposure level and risk.

10.2.4.3 Risk management for the noise hazard

Figure 10.1 illustrates a risk management system for occupational noise. Linkages in the figure indicate relationships and information flow between elements, which should be considered during the HCP review process.

The preferred order of implementation, as far as reasonably practicable, for risk management strategies is, firstly, eliminate the risk by noise control engineering (NCE) that focuses on control of noise at the source, followed by administrative control measures to manage noise exposure where levels cannot be reduced to below 85 dBA and, lastly, personal protection. Despite this ranking of risk control strategies, the significance of the noise hazard and practical constraints generally necessitate a combination of two or more of these, particularly in the short term, such as providing PPE concurrently with the implementation of engineering controls.



HCP: hearing conservation programme, HPD: hearing protection device, HSR: health and safety representative, MHSA: Mine Health and Safety Act No. 29 of 1996, NCE: noise control engineering, OMP: occupational medical practitioner, PPE: personal protective equipment, RBME: risk-based medical examinations

Figure 10.1. Functional structure of a risk management system for occupational noise

Source: Adapted from the MHSA (3)

10.2.5.1 Risk assessment and occupational hygiene monitoring

Risk assessment and occupational hygiene monitoring for the noise hazard should be based on a rational sampling strategy, using personal noise dosimetry as the principal source of data. Sampling must include all occupations, activities/processes, and workplaces, as well as known sources of noise as stipulated in the guideline document for noise exposure (6). Homogeneous exposure groups (HEGs) must be identified for purposes of personal exposure monitoring and clearly demarcated on a plan/sketch of the area.

It is important to note that HEGs need to be reclassified and updated on the plan/sketch when the 90th percentile indicates the need. To ensure accuracy of measurements and appropriateness of risk control measures, all instruments should be electro-acoustically calibrated at 12-month intervals, by a laboratory meeting the requirements of ISO/IEC 17025:2017 (18).

It is advisable to use Type 1 and Type 2 SLMs and dosimeters for NCE measurements and for resolving disputes.

For practicability, observed exposure levels should be classified in accordance with **Table 10.2**, as obtained from a study conducted by Royster, Berger, and Doswell-Royster (19).

Table 10.2. Classification and required action for various levels of personal noise exposure level

Category	Personal exposure level	Action required
A	Exposures ≥ 105 dB $L_{Aeq,\,8h}$	Implement formal hearing conservation programme (6 monthly temporary threshold shift)
B	Exposures ≥ 85–105 dB $L_{Aeq,\,8h}$	Implement formal hearing conservation programme (annual permanent threshold shift)
C	Exposures ≥ 82 dB $L_{Aeq,\,8h}$ and < 85 dB $L_{Aeq,\,8h}$	No special precautions Monitoring required (annual permanent threshold shift if exposed to ototoxic agents)

Observed values to be rounded to nearest decibel

The risk assessment process should result in the prioritisation of all sources of worker exposure, based on a risk rating for noise (RRN) defined as:

RRN = EXPOSURE CLASSIFICATION FACTOR X PERCENTAGE OR NUMBER OF WORKERS AFFECTED

Note: For full-time exposure to a given source, the exposure classification factor is taken directly from **Table 10.2.** For part-time/intermittent exposure, the exposure classification factor is the product of the applicable factor and the source's percentage contribution to total exposure.

Risk rating for noise should serve as the basis for prioritising all sources of exposure (machinery and operations) for interventions, formulated in accordance with the order of preference shown in **Figure 10.1**.

Occupational hygiene measurements should be used to evaluate the control measures implemented and monitor any remaining risks to workers. Regarding the latter, results should also be incorporated or linked with employee records of medical surveillance.

10.2.5.2 Education, motivation, and training

If significant risks exist, the employer is obliged to provide appropriate health and safety training for exposed persons. Education, motivation, and training, fundamental prerequisites to the success of an HCP, must be addressed at all levels in the organisation, not only among noise-exposed workers. The essential purpose is to:

- Instil an awareness of the noise hazard
- Inform and instruct workers regarding risk control measures (such as the use of HPDs, undergoing routine medical surveillance, and reporting any concerns related to the noise hazard)

Educational/motivational and training materials are available from several sources, including manufacturers and suppliers of HPDs and certain machinery, as well as from the MHSC research projects, such as Project SIM 11 05 01 by the CSIR Division of Mining Technology (20).

The materials should:

- Advance a comprehensive understanding of the noise hazard and motivation to prevent hearing loss
- Encourage a positive attitude towards implementation of hearing conservation/risk control measures
- Increase participation and contribution to the success of risk control measures, such as modified work practices and the proper use/care of HPDs

Officials responsible for formulating or implementing hearing conservation/risk control measures should receive training in several aspects, additional to those aimed at workers. Essential learning topics are summarised in **Table 10.3**.

Table 10.3. Learning topics for all workers and responsible officials

Learner topics	Responsible officials
Nature, mechanisms, and consequences of NIHL	Employers and employees are responsible for the requirements for effective health and safety training
Risk factors in the occurrence of NIHL and its potential impact on work, family, and social life	Occupational hygienists are responsible for communication/consulting strategies to facilitate implementation of health and safety training and ensure effectiveness
Recognising dangerous noise in the workplace	Occupational hygienists and mine management are responsible for the development of hazard identification and risk assessment procedures
Means to prevent NIHL	Mine management and occupational hygienists are responsible for the formulation of strategies and workplace procedures for effective risk management
Benefits, use, and care of HPDs	Mine management is responsible for the requirements for an effective personal protection strategy and HPD selection criteria
Legislated requirements	Mine owner and mine management are responsible for compliance with legislative measures for NHIL
CoP and risk management system and measures	Mine management is responsible for the incorporation of noise emission limits into procurement criteria
Communication	Employers and employees are responsible for communicating requirements for compliance
Modified workplace procedures to reduce the risk of NIHL	Mine management is responsible for consultation strategies during the development of risk control measures and revised workplace procedures
Controlling risks	Workers are responsible for communication strategies to facilitate implementation of noise controls
Purpose of occupational hygiene monitoring and medical surveillance	Mine management is responsible for record-keeping systems, administrative, and legal requirements
Workers' role and responsibilities in monitoring hazards and controlling risks	Mine management is responsible for record-keeping systems, administrative and legal requirements

CoP: Code of Practice, HPD: hearing protection device, NIHL: noise-induced hearing loss

Several learning outcomes can be identified as potential contributors to a successful HCP**. Appendix 10.N.1** provides an example of risk management-related learning outcomes, summarised as:

- Developers or providers of training courses should formalise all expected learning outcomes, with due consideration to other requirements, such as those prescribed by the Mine Qualifications Authority.
- On completion of their training, learners should be able to demonstrate the required competencies.
- Educational, motivational, and training programmes should be evaluated and revised on an ongoing basis, such as by comparing the results of pre- and post-tests based on expected learning outcomes, and by considering the findings of HPD compliance monitoring.
- Reinforcement and retention training are also important aspects that should be appropriately addressed and regularly evaluated.

10.2.5.3 Noise control engineering

An HCP must incorporate the element of NCE as a fundamental strategy to address the source of risk. Noise control engineering is the direct responsibility of engineering personnel in the mine management structure, and should include at-source noise reduction, controlling noise transmission through the workplace, and improving machinery maintenance procedures. Machine maintenance should incorporate noise emission measurements as a quality control check for significant noise sources.

Source control measures must be specific to the machinery and work situation and often require specialised input from suitably qualified and experienced individuals, such as the designers and manufacturers of the equipment and acoustics engineering consultants. Where practicable control measures are individually inadequate, appropriate combinations of the following strategies should be considered:

- Adopting alternative methods or processes where suitable technologies are available
- Installing quieter machinery at the time of replacement or plant expansion
- Modifying existing machinery to incorporate noise reduction features of current models
- Implementing measures to control the transmission of noise through the workplace, such as use of enclosures and absorbent interfaces, reflective or absorbent barriers, as well as specialised installation techniques for machinery and reticulation components.
- Relocating major noise sources away from workers, or isolating/enclosing sources or workers

Noise control engineering is the preferred strategy but is initially expensive. It should address the priorities determined during the risk assessment process and confirmed by occupational hygiene monitoring. Noise control engineering initiatives must also incorporate noise standards and emission limits for machinery that are enforced through the employer’s procurement and maintenance policies. Finally, engineering personnel must keep abreast of new developments in technology and machinery design, to ensure ongoing reductions in noise at, or near, the source.

Examples of engineering-based noise control treatments are presented in **Appendix 10.N.2** for a comprehensive presentation of the principles and application of noise and vibration control measures.

10.2.5.4 Administrative measures to control risk

The MHSA implies that where elimination or control is not possible or practicable, minimisation is an acceptable course of action. Despite their limited practicability, administrative measures to change the organisations of work offer potential to reduce individual exposure.

Examples include revised working procedures, such as the relocation or alternative scheduling of noisy operations performed in the same or adjacent areas, and rotation of workers out of noisy areas to quieter activities. The latter requires workers to be competent in multiple tasks and for there to be sufficient work in quieter areas, to accommodate individuals approaching their exposure limit. Worker rotation may be limited by its likely impact on productivity, and by the potential safety and productivity implications of workers being less familiar with certain tasks.

Use of worker rotation would also impose the additional administrative burden of quantifying and documenting individual worker's exposure, based on noise levels and exposure durations in each of their workplaces. The potential contribution of administrative measures to successful risk management should be evaluated but is likely to be restricted to changes in work organisations, such as staggered scheduling and/or the relocation of noisy tasks.

10.2.5.5 Personal protection

Where NCE and administrative measures fail to reduce risks sufficiently, a personal protection strategy based on the use of HPDs is indicated. However, this approach should be regarded as a last resort, and as a temporary supplement to the preferred elements of risk management. The essential prerequisites of education, motivation, and training, as well as risk-based medical examinations (RBMEs), must be in place before reasonable benefits can be derived from a personal protection strategy.

- *Risk-based medical examinations*

The RBME should be incorporated into existing medical examination procedures for all individuals who will be exposed to hazardous noise. The RBME is intended to identify:

- any contra-indication for an employee or prospective employee to work in noisy areas, including safety issues (inability to hear warning signals while wearing HPDs) or health concerns (an abnormal susceptibility to hearing loss, or to outer ear infection that could be exacerbated by insertable HPDs); and
- any anatomical abnormality or temporary medical condition that could negatively influence the appropriate use of HPDs, or the validity and reliability of the audiometric findings.

An occupational health practitioner should perform RBMEs as part of monitoring examinations and re-examinations, in cases where a worker's relocation involves a change in workplace noise levels for the worse. The RBME for noise exposure should consist of the following four elements:

- Confirmation of current eligibility for audiometry, by examining the external and middle ears for possible pathology, such as otoscopic examinations
- Hearing protection device compatibility assessment, such as an examination of the external ear canals to confirm their compatibility with HPDs, particularly where insertable types may be used, and identification of any limitations imposed by external ear anatomy
- Special needs assessment, where the results of previous audiometry indicate significant hearing loss, to consider the use of low-attenuation HPDs for enhancing communication and perception of warning signals in noise
- A participative decision regarding allocation to noisy areas, where current and previous audiometry indicate an abnormal susceptibility to NIHL

To inform and facilitate the HPD selection process, the HPD compatibility and special needs assessments should result in classification according to **Table 10.4.**

Table 10.4. Classification from hearing protection device compatibility and special needs assessments

Employee classification	Interpretation/additional information required
No restriction	No medical/anatomical contra-indications for any HPD type
Restricted use of HPDs, either: • Permanent restriction • Temporary restriction	Details of restriction imposed, in accordance with underlying reasons Indication of temporary restriction's likely duration, or criteria for removal of restriction
Change from current HPDs recommended	Reasons for the change, and provide alternatives
Exclude insertable HPDs	Reasons for restriction, and criteria for alternative devices
Issue custom-moulded HPDs	Reasons/motivation for classification and selection criteria
Issue low-attenuation HPDs	Attenuation criteria, relative to audio frequency
Any other classification deemed appropriate by examiner	Reasons for classification; recommended course of action

HPD: hearing protection device

- *Selection of hearing protection devices*

Selection, fitment, and hands-on instruction in the application of HPDs should be conducted during, or immediately after, the RBME, under the direct supervision of an occupational health practitioner (OMP).

The noise reduction rating (NRR) is determined under controlled laboratory conditions that are not representative of the workplace, and ratings cited by manufacturers should be used only for comparative purposes. Thus, a 50% de-rating is commonly recommended to compensate for the optimal protection levels indicated by NRR, but only after an initial 7-dB reduction in rating for cases where A-weighted workplace measurements are used.

Some HPD manufacturers use the octave-band (long-method computation), real-ear attenuation at threshold (REAT), or high, medium, low (HML) methods to characterise their products' protection levels. The octave-band method is preferred, because it facilitates the matching of HPD attenuation with the noise environment (see tabulated example in **Appendix 10.N.3**).

Conventional HPDs are classified according to their manner of application, as indicated in **Table 10.5.**

Table 10.5. Conventional hearing protection device types

Type of HPD	Description/example
Circum-aural	Enclose or surround the ears, such as earmuffs and earmuffs equipped with communication interfaces to enable effective communication in noisy environments
Extra-aural	Seal the entrance to ear canal, such as ear caps
Intra-aural	Inserted into ear canal, such as earplugs, including: foam earplugs, and pre-moulded, either: • Moulded for a specific individual, or • Where pre-fitted to the ear canal

HPD: hearing protection device

The selection process must consider the findings of individuals' HPD compatibility and special needs assessments, as well as workplace ergonomics and environmental conditions. Factors to be considered during the HPD selection process are summarised below:

- The level and nature (relative to frequency) of protection provided by HPDs must be matched with the noise environment. Excessive attenuation causes sensory deprivation and interference with communication, to the potential detriment of safety and productivity. Individuals with significant pre-existing hearing loss may require specially selected low-attenuation HPDs. In addition, any anatomical abnormalities of the external ear must be accommodated.
- Environmental/physical conditions and work rates may render some HPDs unsuitable for certain situations, despite their other attributes (earmuffs would be inappropriate for hot and humid conditions, and where heavy physical exertion or confined workspaces are a factor).
- Hearing protection devices must be compatible with other PPE that will be used, such as hardhat, safety glasses/goggles, or respiratory equipment.

It is important that workers can choose from a reasonable selection of HPDs that are both appropriate for the intended application and compatible with individual requirements. Initial fitting by individual users should be supervised and facilitated by the OMP.

- *Compliance monitoring*

Hearing protection device usage should be monitored as a measure of the personal protection strategy's effectiveness. Monitoring by trained personnel, using random sampling, should be conducted on an ongoing basis and be documented to assess the appropriateness, acceptability, and availability of devices being issued, as well as to provide input to the review of education, motivation, and training, RBMEs, HPD selection/procurement criteria, and distribution methods – at least quarterly. Findings should be considered during the HCP review, to formulate appropriate revisions.

- *Hearing protection device fitment process flow*

The HPD fitment process includes the following components:

a) Risk Based Medical Examination - Worker undergoes RBME as per mine standard. The outcome can either be fit to work with HPD or requires further assessment

b) Referral to occupational health centre (OHC) - Based on the RBME outcomes, the OHC conducts audiometry (baseline or periodic) and confirms need for HPD based on exposure profile and medical findings. If medically unsuitable for standard HPD, the matter is escalated to OHS Officer for alternative controls.

c) HPD selection and fitment (OHC & training centre) - The responsibilities of OHCs include selection of appropriate HPD type based on noise exposure level, job task, worker anatomy and compatibility with other PPE. OHCs also issues referral to training centre for fitment and competency training. The responsibilities of training centres include conducting HPD fitment session (e.g., earplug fit testing, earmuff adjustment, providing practical training on correct insertion/placement, care and maintenance and limitations of HPDs as well as recording of fitment results and worker competency.

d) Supervisor verification - once the HDP is selected, the supervisor confirms that worker has completed HPD fitment and training and that correct HPD is issued and used consistently. The supervisor also conducts routine workplace checks and coaching and reports noncompliance or fitment issues to OHS Officer.

e) Occupational health and safety officer oversight - Occupational health and safety officers are required to review HPD selection, fitment records, and compliance trends, investigate repeated failures, discomfort reports, or exposure exceedances, ensure engineering and administrative controls are considered before relying on HPDs and provide feedback to OHC, training centre, and supervisors for continuous improvement.

f) Periodic review - At the next RBME or periodic audiometry, HPDs are assessed for effectiveness of use, identification of early signs of NIHL is done and adjustment of HPD types or fitment is done. Additionally, worker records are updated and notification of any changes relayed to the supervisor and OHDS officer

10.2.5.6 Medical surveillance

Medical surveillance is the direct responsibility of occupational health professionals and OMPs. Audiometry is used to monitor the impact of noise on workers' hearing and evaluate measures aimed at controlling NIHL.

10.2.5.6.1 Legal basis

Noise is regarded as a 'significant' hazard,' where workers' TWA equivalent exposure levels exceed 50% of the occupational exposure limit (> 82 dB, in accordance with the 85-dB rating limit and 3-dB exchange/doubling rate stipulated by SANS 10083:2023). In such cases, the MHSA and the Occupational Hygiene Regulations encourage the employer to implement a mandatory CoP and occupational hygiene monitoring. When persons are subjected to an occupational health hazard, such as an equivalent exposure level exceeding the exposure limit of 85 dB, then section 13(1) of the MHSA requires the employer to establish and maintain an appropriate system of medical surveillance (as defined in section 102 of the Act). Additionally, annual audiometry should be conducted if noise exposure levels exceed 82 dB and if there is exposure to ototoxins at work.

The MHSA further requires that medical surveillance programmes be designed to provide the employer with information that enables the elimination, control, or minimisation of the hazard and associated risks. This indicates that linkages must be established between the results of noise exposure determinations (occupational hygiene and risk assessment measurements) and records of medical surveillance. Where such linkage is not possible on an individual basis, it should be based on occupation, activity, and/or workplace.

10.2.5.6.2 Application and frequency of audiometric testing

Audiometry is the process where an individual's hearing threshold levels are determined over a specified range of hearing frequencies from 250 Hz to 8 000 Hz. Routine screening audiometry employs basic pure-tone air-conduction techniques to record baseline, periodic screening, monitoring, and exit audiograms.

Diagnostic audiometry evaluations incorporate additional techniques, such as bone-conduction, speech audiometry, and/or otoacoustic emissions testing to diagnose NIHL. The application, purpose, and procedural requirements for the several types of audiometry are summarised in **Table 10.6**.

Table 10.6. Application, purpose, and procedural requirements for audiometric testing

Type of audiometry	Application	Purpose	Procedural requirements
Baseline	Before allocation to work in a noise zone (TWA ≥ 85 dB) or within 30 days of commencing such work	To provide a reference for evaluating any future changes in hearing status	Before testing, a 16-hour period with no exposure to noise > 85 dB (use of HPDs complying with SANS 1451- 1, 2, or 3 is NOT acceptable) Use better of two audiograms that are within 10 dB at 0.5, 1, 2, 3, and 4 kHz Where consistency is not possible or pathology is suspected, refer for medical opinion to consider possible audiologist or specialist evaluation Incorporate results into medical surveillance records
Periodic screening	Annually for noise-exposed individuals (TWA ≥ 85 dB)	To detect any early NIHL (early flags) and take action before this gets worse	Before testing, a 16-hour period with no exposure to noise > 85 dB (use of HPDs complying with SANS 1451- 1, 2, or 3, as appropriate, is acceptable) Incorporate results into medical surveillance records
Monitoring	Six-monthly for high-risk exposure (TWA > 105 dB), subject to employer's CoP	To identify temporary threshold shifts and enable the prevention of permanent hearing loss To evaluate the efficacy of HPDs	Conduct testing as soon as possible after exposure to noise, such as at the end of the working shift
Exit	On conclusion of employment in a noise zone (TWA ≥ 85 dB) or on employee's termination	To provide a record of hearing levels on conclusion of employment in a noise zone	Before testing, a 16-hour period with no exposure to noise > 85 dB (use of HPDs complying with SANS 1451- 1, 2, or 3, as appropriate, is acceptable) Incorporate results into medical surveillance records
Diagnostic	When medical opinion recommends a specialist evaluation for the purpose of investigating ear pathology When inconsistent baseline results, or a potential compensation claim for NIHL	To enable a specialist evaluation of hearing status as required To support a possible compensation claim, where indicated	Before testing, a 16-hour period with no exposure to noise > 85 dB: *N.B. Use of HPDs to limit noise emission during this period is NOT ACCEPTABLE*; To determine eligibility for compensation, two audiograms must be recorded during two different sittings (both may be on same day). If the two differ by more than 10 dB for either ear at any mandatory test frequency (0.5, 1, 2, 3, 4, 6, or 8 kHz), then a third audiogram must be recorded during a third sitting Where third audiogram also indicates inconsistencies > 10 dB, subject should be re-evaluated in six-month's time. Thereafter, if consistent results are still not

			obtainable, subject may be referred for further specialist evaluation of hearing loss; incorporate results into medical surveillance records

HPD: hearing protection device, SANS: South African National Standard, TWA: time-weighted average

10.2.5.6.3 Equipment requirements

The requirements for screening and diagnostic audiometers are presented in **Table 10.7**.

Table 10.7. Audiometer requirements

Type of audiometer	Test frequencies	Specification
Screening	0.5; 1; 2; 3; 4; 6, and 8 kHz	Type 4 (IEC 60645-1:2017)
Diagnostic	0.25; 0.5; 1; 2; 3; 4; 6, and 8 kHz	Type 3 (IEC 60645-1:2017)

Acoustic enclosures or 'soundproof' rooms, for screening or diagnostic audiometry, must comply with the relevant requirements for background noise and environmental conditions stipulated in SANS 10182: 2006 (21). This Standard provides background noise limits (in unweighted decibels) for air-conduction, bone-conduction, and sound field audiometry, as listed in **Table 10.8**.

Table 10.8. Background noise limits for audiometry

Type of audiometry	Maximum unweighted sound pressure level (dB) at given centre frequency (Hz): SANS 10182: 2006						
	125	250	500	1 000	2 000	4 000	8 000
*Screening	52.0	38.5	22.0	24.0	31.0	37.0	35.5
Diagnostic:							
Air-conduction	29.0	21.0	20.5	24.0	31.0	37.0	35.5
Bone-conduction	22.5	14.5	10.5	9.5	9.0	5.0	12.5
Sound field	19.0	11.5	7.5	9.5	6.0	2.0	11.5

*Baseline, periodic screening, monitoring, and exit audiometry using air-conduction methods

10.2.5.6.4 Audiometer calibration and verification

Screening and diagnostic audiometers should have a valid calibration certificate at the time of commissioning. The supplier normally provides an initial certificate after on-site calibration, and, thereafter, on-site electro-acoustic calibrations must be performed annually in accordance with SANS 10154:2020. Calibration service providers should have the necessary training and equipment and demonstrate traceability to the National Acoustics Standard (Measuring Units and National Measuring Standards Act No. 76 of 1973). SANS 10725/ISO/IEC 17025 (18) prescribes the general requirements for the competence of testing and calibration laboratories. Calibration details for the service provider's instruments must appear on the audiometer's calibration certificate. Audiometer calibration certificates should be retained for record keeping and inspection purposes, as well as for validating audiometric test results in cases of dispute.

Personnel conducting audiometry should confirm the accuracy and calibration continuity of screening and diagnostic audiometers on a daily and weekly basis, as required by SANS 8523-1-2011, by means of subjective or biological calibration checks. These procedures involve the recording of a calibration reference audiogram, using a calibration subject with known and stable hearing threshold levels (calibration subjects must not have hearing threshold levels exceeding 25 dB at any test frequency, or be routinely exposed to excessive noise). The subject's weekly audiogram from a given audiometer is compared with the calibration reference audiogram. Where the two values differ by 10 dB or more, the audiometer should be immediately withdrawn from service for repair and electro-acoustic re-calibration. Thereafter, a new calibration reference audiogram must be recorded before the instrument is returned to service.

Records of all subjective or biological calibrations, including calibration reference audiograms, should be retained for record keeping and inspection purposes, as well as for validating audiometric test results in cases of dispute.

Each day, prior to testing, personnel conducting audiometry should:

- Confirm the correct function of the audiometer
- Inspect all cables and connections
- Confirm the proper function of the patient response button
- Perform listening checks to ensure the absence of unwanted or extraneous sounds, such as hums, licks, or distortion [at a minimum of three hearing level (HL) or loudness settings for each test frequency]

If unwanted or extraneous sounds occur, then the audiometer should be withdrawn from service for inspection and possible repair, after which an electro-acoustic calibration should be performed and a new calibration reference audiogram recorded.

10.2.5.6.5 Qualifications and registration of personnel conducting audiometry

Qualification and registration requirements for personnel conducting audiometric tests, as recommended in a review study by Moroe et al. (2018) (22), are summarised in **Table 10.9**.

Table 10.9. Requirements for personnel conducting audiometric tests

Requirements for personal conducting	
Screening audiometry (baseline, periodic screening, monitoring, and exit)	**Diagnostic audiometry (specialist evaluations)**
Audiometrist registered with the SASOHN as an audiometrist or hearing aid acoustician, or holding a certificate in audiometry issued by an institution recognised and approved by the DMPR	Audiologist, such as a graduate in audiology or speech therapy and audiology, registered with the HPCSA
Occupational medical practitioner registered with the HPCSA Audiologist, such as a graduate in audiology or speech therapy and audiology, registered with the HPCSA	
Medical practitioner specialising in otorhinolaryngology and registered with the HPCSA	Medical practitioner specialising in otorhinolaryngology (ENT specialist) and registered with the HPCSA

DMPR: Department of Mineral and Petroleum Resources, ENT: ear, nose, and throat, HPCSA: Health Professions Council of South Africa, SASOHN: South African Society for Occupational Health Nursing Practitioners

Source: Moroe et al. (2018) (22)

10.2.5.6.6 Medical opinion in cases of hearing loss

In complex cases, or where permanent disability is likely to exceed 15% (such as impairment > 30%) or a cumulative shift in percentage loss of hearing (PLH) equalling or exceeding 10% from the original baseline in accordance with circular instruction No. 171 is confirmed, the opinion of an otorhinolaryngologist (ear, nose, and throat (ENT) specialist) should be obtained. In all other instances where the hearing loss is judged to be noise related, the medical opinion should be that of an OMP.

10.2.5.6.7 Audiometric testing procedures

Audiometric testing should be preceded by instruction in the procedures and an orientation phase to confirm subject competence, by observing responses to preliminary test signals. The test phase follows, during which hearing threshold levels are measured and recorded. According to the International Organization for Standardization (ISO) 6189 (23), one of two methods may be used, either the ascending or the bracketing method. Given its simplicity, the ascending method is recommended. The order of test frequencies and procedures for determining threshold are listed in sections 10.N.4.1 and 10.N.4.2, respectively, of **Appendix 10.N.4**.

10.2.5.6.8 Information to be recorded.

Information to be recorded in audiometry records and incorporated into medical surveillance records is summarised in **Table 10.10.**

Table 10.10. Information to be included in records of audiometry

Information to be recorded or readily apparent	Type of audiometry	
	*Routine	Diagnostic
Name, identity number, company number, and age	X	X
Method used for positive identification, such as ID, ID card, or similar with photograph		X
Occupation, details of work, date of employment	X	X
Noise and exposure levels from occupational health monitoring, as relevant to individual, occupation, or workplace, including levels for previous allocations and period of previous allocations	X	X
Name, address, qualifications, and registration number of person conducting audiometry	X	X
Early Lag indicators exceeding 10dB shift from baseline (or 3 years ago) in the average of the low frequencies of 0.5, 1 and 2 or exceeding 15dB shift from baseline (or 3 years ago) in the average of the high frequencies of 3, 4 and 6 or 4 kHz notch	X	X
Relevant medical history, such as medication, colds, allergies, excessive ear wax, and ear pathology	X	X
Baseline audiometric data and corresponding PLH (Refer to Section 10.2.5.6.9 below for PLH details.)	X	X
Current air-conduction hearing threshold levels and PLH routine: 0.5; 1; 2; 3; 4, and 6 kHz. Diagnostic: 0.25; 0.5; 1; 2; 3; 4; 6, and 8 kHz	X	X
Current bone-conduction hearing threshold levels (0.25; 0.5; 1; 2; 3; 4; 6, and 8 kHz) and PLH		X
Current hearing threshold levels derived from speech discrimination, or any other audiometric techniques applied		X
Relevant comments regarding response to testing	X	X
Details of any actions taken/recommended on the basis of results	X	X
Copies of any medical opinions obtained, with names and addresses of individuals providing them	X	X

Assessment of the possibility of a causal relationship between any abnormalities/threshold shifts and occupational (or other) noise exposure, or of a link with any other cause(s)		X
Signature of audiologist or medical specialist		X

ID: identity document, PLH: percentage loss of hearing

*Baseline, periodic screening, monitoring, and exit audiometry

Records of all audiometry, diagnostic or routine, must be maintained in accordance with legal requirements of sections 15 (1) and (2) of the MHSA. Thus, computer-based systems should have adequate, reliable backups to ensure that data are not lost.

10.2.5.6.9 Early Lag Indicators

Early lag indicators are the principal criteria for assessing hearing status of NIHL. These are the subtle, often easily overlooked signs that damage is already occurring before a measurable permanent threshold shift appears. These indicators are incredibly valuable in occupational health because they allow you to intervene before the worker crosses into compensable or irreversible loss. The following should be included in the surveillance protocols and training materials:

- A short-term reduction in hearing sensitivity after noise exposure that recovers within hours
- A small dip at 4 kHz (or sometimes 6 kHz) that is not yet deep enough to classify as NIHL, may be unilateral or bilateral or often fluctuates between tests
- A gradual worsening of thresholds at 3, 4, or 6 kHz over successive audiograms, even if the shift is less than 10 dB, it does not meet the mine's definition of a STS and trend analysis is critical.
- Early Onset Tinnitus where workers report ringing, buzzing and hissing
- Difficulty Hearing Speech in Noise
- Increased HPD Dependence
- Complaints of Aural Fullness or Pressure
- Repeated Minor Fitment or Comfort Issues
- Early Cognitive Listening Fatigue

10.2.5.6.10 Evaluation of hearing status and criteria for compensation claims

Shifts in PLH are identified by comparing the current value with that from the baseline audiogram (for cumulative shifts), or with previous audiograms (for interim shifts).

Percentage loss of hearing is derived from combining the individual's hearing threshold levels (hearing losses) at 0.5; 1; 2; 3, and 4 kHz, using tables available from the Compensation Commissioner. A shift of 10% or more in PLH, as compared with the baseline audiogram, has been accepted as the level at which a compensation claim may exist (15). In such instances, the employer is obliged to make a submission to the Compensation Commissioner or relevant mutual association within 14 days of becoming aware of the shift in PLH, irrespective of any agreement or dispute with the case's merits or validity.

10.2.5.7 Review of the hearing conservation programme

The various elements of an HCP require regular review, the interval being dependent on their nature and role within the overall programme. Evaluations for individual aspects should be reported on completion, with interim findings being incorporated into a comprehensive report on HCP effectiveness.

10.2.5.7.1 Risk assessment and occupational hygiene monitoring

The quantification and monitoring of noise emission and exposure levels, as well as the prioritisation of noise sources for possible intervention, are normally performed by the occupational hygienist with input from the risk assessment process. Changes include the replacement, major overhaul, upgrading, or expansion of noisy plant or machinery, the implementation of noise reduction or control measures, as well as the addition/removal of walls, partitions, doors, and windows. Exposure levels are best determined by ongoing personal noise dosimetry.

Findings should be reviewed and evaluated quarterly or at six-month intervals (as appropriate), in terms of previous results and targets or key performance indicators (KPIs) adopted by the HCP management or health and safety committee (HSC) and agreed to in advance of their application. Where the review process indicates an unfavourable trend or failure to achieve an agreed target, then the relevant personnel should take appropriate action.

10.2.5.7.2 Education, motivation, and training

Although HPD usage provides some measure of effectiveness, other forms of evaluation, such as pre- and post-training knowledge checks, can identify outstanding training needs and revisions required for training subsequent groups. Training personnel or health and safety representatives (HSRs) should evaluate reinforcement and retention training, by means of workplace interviews and questionnaires.

Appropriate KPIs would include shifts in workers' attitudes towards hearing conservation and compliance with risk control measures. Review and evaluation of education/motivation/training initiatives should be conducted on a quarterly to six-monthly basis, with revisions implemented as soon as the need becomes apparent.

10.2.5.7.3 Engineering-based source and transmission control

Measures to reduce noise at source, and control its transmission through the workplace, would normally be evaluated by considering emission and exposure levels. The nature of significant noise sources and their risk-based prioritisation determine what control measures should be applied. A review of the NCE strategy includes measurement-based evaluations of steps already taken, with pre-implementation levels and agreed targets serving as the basis for KPIs.

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The NCE review should also examine plans for future interventions to ensure their appropriateness, feasibility, and compliance with priorities established during risk assessments and confirmed by occupational hygiene monitoring. Ultimately, audiometric testing will provide a measure of NCE effectiveness, but such trends will only emerge after hearing losses have already occurred.

The review interval depends on the number of significant noise sources and the complexity of corrective measures but should be no longer than one year nor less than three months. Standards, limits, targets, and KPIs for noise emission and exposure levels should be reviewed and revised annually.

10.2.5.7.4 Administrative control measures

Evaluation of administrative control measures rely mainly on results of personal noise dosimetry (as a prospective indication) and medical surveillance/audiometry (retrospective), both compared with previously set KPIs. Given the need for a reasonable number of samples to demonstrate trends, a review period of three-to-six months would be required for dosimetry-based evaluations, while those based on audiometry would normally require a 12-month review period.

10.2.5.7.5 Personal protection

A comprehensive review of the personal protection strategy is relatively complex. Workers' use of HPDs provides an immediate indication of the strategy's efficacy and, accordingly, compliance should be monitored on an ongoing basis, with results reviewed at quarterly intervals. Poor compliance levels may indicate inadequacies in the range of HPDs offered (including their appropriateness regarding attenuation and individual/workplace ergonomics), the application of RBME procedures, as well as the effectiveness of education/motivation/training initiatives and HPD distribution procedures.

Individual workers' audiometric trends are the definitive measure of a personal protection strategy's effectiveness. Combined with the findings of HPD compliance and occupational hygiene monitoring, they can be used to evaluate the effectiveness of HPD usage as proactive tools for RBME and certain aspects of the RBME. A 12-month period is normally required for audiometric trends useful to the review process to emerge (24). Key performance indicators for the personal protection strategy should provide a measure of the extent to which worker compliance is maintained, or improved, and shifts in hearing threshold levels of above 25 dB (24). Both require the comparison of current and previous results and agreed targets.

10.2.5.7.6 Medical surveillance/audiometry

Audiometry for noise-exposed workers remains the ultimate indicator of HCP effectiveness, as it measures hearing losses that the programme should prevent. Shifts and trends in hearing thresholds for the entire workforce and subgroups are vital for HCP evaluation. Shifts in hearing threshold levels refer to changes in the quietest sounds a person can hear, either temporarily or permanently (25). These shifts can be measured through audiometric testing and are often categorised as temporary threshold shift (TTS) or permanent threshold shift (PTS). Identifying those occupations, workplaces, and activities where hearing loss is progressing most rapidly, particularly in the case of a large workforce, normally requires the use of audiometric database analysis (ADBA) techniques (19). To ensure their validity, ADBA-based assessments should include the indirect impact of NIHL on workforce turnover, by identifying and addressing hearing loss risks within the designated HEGs. The workforce is divided based on occupation, activity, and/or workplace, as appropriate, to evaluate the relative influence of noise on collective hearing status in these categories. This involves the use of average values, distributions of values, or prevalence of critical shifts for one or more of the following parameters (26):

- Audiometric category, particularly with respect to the higher test frequencies of 3, 4, and 6 kHz, which are most susceptible to the effects of noise exposure
- Average or total threshold shift at 3, 4, and 6 kHz
- Threshold shift at 4 kHz only
- Percentage loss of hearing

The choice of parameter(s) and means of analysis depend on the audiometric test system's data management capabilities, and suppliers should be asked to provide enhancements where required. This should not pose a serious constraint in the case of locally developed software, particularly if consensus on requirements can be reached at group level, or on an industry-wide basis.

Noise-exposed workers should undergo audiometric testing annually but, depending on the employer's CoP, those performing high-risk work (8-hour TWA equivalent noise exposure > 105 dB) may be tested every six months. Accordingly, the results of medical surveillance should be reviewed at similar intervals, such as annually or six-monthly, as applicable.

Reports for medical surveillance should include current and previous results, as well as KPIs set by the HCP management or HSC and an analysis of the comparisons. Occupations, activities, and workplaces where the greatest prevalence and extent of hearing loss are apparent should be highlighted and prioritised for risk control interventions.

10.2.5.7.7 Overall review of the hearing conservation programme

A comprehensive review of the HCP should be compiled annually and incorporate, at least in summary form, interim findings for various elements and sub-elements of the programme. The review should present actual and targeted values for KPIs, and priorities areas for intervention. It should also incorporate action plans, with clearly defined evaluation criteria and assignments of responsibility. Critical aspects of the HCP review process are summarised in **Table 10.11**.

Table 10.11. Summary of hearing conservation programme review requirements

Programme element	Evaluation parameters/indicators	Review period	Basis of KPIs
Risk assessment and occupational health monitoring	Emission and exposure levels: number/percentage of workers affected	Quarterly/six-monthly	Variance with previous findings and with agreed targets
Education, motivation, and training	Level of knowledge and skills measured by pre- and post-education, motivation and training tests	Quarterly/six-monthly	Collective variance between pre- and post-education, motivation, and training results
	Employee attitudes and behaviour determined by workplace interviews/questionnaires/ observations		Shifts in employee attitude or behaviour
	HPD compliance level; audiometric trends		Variance with previous findings and targets
Noise control engineering	Noise emission and exposure levels	Quarterly/annually	Variance with previous findings and targets
Administrative control measures	Individual exposure levels	Quarterly/six-monthly	Variance with previous findings and targets
	Individual audiometry results	Annually	
	Audiometric trends	Annually	
Personal protection	HPD compliance levels	Quarterly	Variance with previous finding and targets
	Audiometric trends	Annually	
Medical surveillance /audiometry	Average values, distributions of prevalence of critical variance in: • Audiometric category, particularly regarding 3, 4, and 6 kHz • Threshold shifts at 3, 4, and 6 kHz; • Percentage loss of hearing	Annually or six-monthly, as appropriate	Variance with previous finding and targets

HPD: hearing protection device, KPI: key performance indicator

10.2.5.2 Hearing conservation programme coordination and management

Implementing, monitoring, and reviewing an HCP requires close coordination and effective management by a suitably qualified and experienced HCP coordinator. The HCP coordinator should command sufficient authority and possess the requisite leadership skills for managing the activities of a multidisciplinary team of specialists.

The hearing conservation management committee (HCMC) should liaise with the HSC and include, in addition to the HCP coordinator, senior personnel from the following departments or disciplines:

- Senior management (Chair)
- Environmental safety/occupational hygiene/ventilation or equivalent
- Risk management/loss control or equivalent
- Engineering
- Mining

- Metallurgy/plant/refinery
- Occupational health/medical services
- Human resources/personnel
- Training and development
- Services, such as transport, procurement

Members of the HCP management committee should assume primary responsibility for aspects/elements of the HCP, according to their function in the organisation. This responsibility cannot be delegated.

10.3 Vibration: Health Effects and Controls

10.3.1 Extent of problem

Exposure to vibration can lead to physical injury, the severity of which is dependent upon duration of exposure and the type of vibration emitted by the tool or machinery. Literature continues to offer insights into the impact on health of poor ergonomics in heavy metal industries such as mining (27). Consequences of vibration-induced injury include poor job performance, reduced efficiency, poorer quality of life, and disability (28).

Vibration-induced disease is recognised and well documented from many parts of the world, including the SAMI (29), and the Regulations and Standards for vibration are presented in **Appendix 10.V.1**. The likelihood of disease is higher with increased working hours, heightened by extended exposure to vibration.

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Vibration-induced disease can be divided into two main areas:

- Whole-body vibration (WBV) and vibration affecting the upper limbs
- Hand-arm vibration syndrome (HAVS), affecting the fingers, hands and arms

Both WBV and HAVS affect the musculoskeletal system, progressively causing musculoskeletal disorders (MSDs) due to prolonged exposure to occupational vibrations. In the mining industry, WBV is associated with operators of transport equipment such as trucks and locomotives. Hand-arm vibration syndrome is associated with handheld or hand-controlled tools such as rock drills.

Problems in defining vibration-induced disease include relating vibration exposure to health effects, the latent period before onset of symptoms, the lack of simple diagnostic tests, distinguishing vibration-induced disease from other disease processes, and confounding factors such as posture and temperature.

The Safety in Mines Research Advisory Committee (SIMRAC) commissioned two studies (i.e. Health 702 (30) and 703 (31)) in 2003 and 2006, respectively, to investigate HAVS, WBV, and musculoskeletal disorders in the SAMI.

A summary of the results obtained is depicted in **Tables 10.12–10.16**.

Table 10.12. Percentage of work-related musculoskeletal disorder-related cases, and associated body part

Commodity	WMSD-related (%)	Body part (%)		
		Upper limb	Lower limb	Back
Gold mine	16.2	15	16	69

Platinum mine	41.3	62	8	30

WMSD: work-related musculoskeletal disorder

Table 10.13. Percentage of work categories that develop work-related musculoskeletal disorder

Commodity	Work category	%
Gold mine	Rock drill operators	43
	General stop team workers	14
	Mechanical loaders	12
Platinum mine	Rock drill operators	18
	Scraper winch operators	5
Colliery	Continuous miner operator	12
	Shuttle car drivers	8
	Fitters	7

Table 10.14. Percentage of musculoskeletal disorder-related cases

Commodity	Cases (%)
Gold mine	1.8–4.5
Platinum mine	1.2–5.9
Colliery	8.9–9.5

Table 10.15. Most common musculoskeletal disorder-related cases and associated body part

Commodity	Body part	%
Gold mine	Backache	82.1
	Hip pain	5.5
	Foot pain (region)	4.6
Platinum mine	Backache	37.8
	Knee pain	17
	Ankle pain	9
	Neck pain	9.1

Colliery	Backache	66.2
	Neck pain	13.5
	Foot pain	8.1

Table 10.16. Percentage of work categories that develop backache

Commodity	Work category	%
Gold mine	Rock drill operators	28.1
	Winch operators	22.3
Platinum mine	Rock drill operators	17.7
	General team category	39.2
Colliery	Shuttle car drivers	18.4
	Belt operators	18.4
	Artisans	18.3

The Health 703 study results showed high prevalence of HAVS in both gold and platinum miners exposed to rock drilling.

Both the Health 702 and 703 studies confirmed association between the development of HAVS and operations known to expose workers above the recommended hand-arm vibration (HAV) exposure limits.

10.3.2 Whole-body vibration

10.3.2.1 Scope of problem

Large numbers of workers in the SAMI are exposed to WBV with unknown consequences. Delivery vehicles, forklift trucks, trucks, tractors, buses, and loaders are the most frequently reported sources of WBV. The most prevalent vibration is found in the frequency range 2–80Hz, and the entire range influences the body.

A systematic literature review by Lings and Leboeuf (32) reported back pain to be more frequent in workers exposed to WBV, and one study showed an increased frequency in lumbar prolapse. At low vibration frequencies of less than 20 Hz, symptoms of motion sickness have been reported along with general symptoms of discomfort. This type of vibration can also impair visual perception and the ability to control a vehicle.

The most common self-reported symptom associated with WBV exposure is lower back pain. Less well documented is sciatic pain, gastrointestinal tract disturbances, and dizziness. In female workers, disturbances of the urogenital tract have been reported, with menstrual disorders and spontaneous abortion being the most common. The clinical findings associated with WBV are degenerative changes in the spine and intervertebral disc disorders. There are, however, no signs and symptoms that are specific to WBV.

As lower back pain is a common complaint, many factors must be considered before ascribing symptoms to WBV. These include:

- Posture of the worker
- Force needed to perform tasks
- 10 Repetitiveness of tasks
- Duration of exposure

Workers often have additional tasks to perform. For example, a vehicle driver may also be involved in loading the vehicle or maintaining it. Repeated climbing in and out of large vehicles, and other activities related to the work of drivers, may lead to back pain, which cannot be distinguished from the effects of vibration. Individual characteristics such as gender, age, strength, and health status may also have a bearing on susceptibility to back pain, along with anthropometric factors such as the height, weight, and length of limbs of the driver or operator.

10.3.2.2 Sources of exposure

Whole-body vibration is usually associated with the driving or operation of transportation equipment. Vibration can be due to the machinery itself or the road surface. The following values give approximate indications of likely reactions to various magnitudes of vibration from vehicles. 10

- Less than 0.315 m/s^2 – Not uncomfortable
- 0.315 to 0.63 m/s^2 – Slightly uncomfortable
- 0.5 to 1 m/s^2 – Fairly uncomfortable
- 0.8 to 1.6 m/s^2 – Uncomfortable
- 1.25 to 2.5 m/s^2 – Very uncomfortable
- Greater than 2 m/s^2 – Extremely uncomfortable

In the mining industry, equipment has been categorised in terms of risk, according to levels of vibration as listed in **Table 10.17**.

Table 10.17. Equipment categories according to levels of vibration

Equipment	Risk
Articulated dump trucks	High
Bulldozers	High
Front-end loaders	High
Hydraulic shovels	High
Tractor tippers	High
Underground locomotives	Moderate
Load haul dumpers	Moderate
Shuttle cars	Low

Draglines	Low

The risk rating should be used as a general guide, since machinery may cause different vibrations under different operating conditions. For example, if not properly maintained, an engine may vibrate excessively. Poor or worn suspension systems and the condition of the road will influence the vibration transmitted to the vehicle driver. Therefore, all vehicles are a potential source of WBV.

10.3.2.3 Standards

While South Africa has studies on WBV in the mining industry, there is no definitive evidence of a widespread, compensable occupational disease linked to WBV. Research has struggled to establish a clear dose-response relationship between WBV and lower back pain (LBP), a common complaint. However, studies have shown high vibration levels on various mining equipment, and the possibility that these exposures contribute to back and neck injuries.

The South African Bureau of Standards (SABS) has adopted SANS 2631-1:2017 and SANS 2631-2:2018 as Standards for measuring whole-body vibration. Other Standards are discussed in **Appendix 10.V.1**

10.3.2.4 Monitoring

Monitoring for WBV takes the form of measuring vibration by placing accelerometers under the seats of vehicles. The Standards for measuring equipment are covered in ISO 8041-1 (**Appendix 10.V.1**). Additionally, Chapter 16 of the MHSC's *Handbook on Mine Occupational Hygiene Measurements*, outlines the requirements for employers to establish and maintain systems for occupational hygiene monitoring of vibrations and medical surveillance, including risk assessments, monitoring programmes, and control measures (33).

10.3.2.5 Control

Vibration characteristics should be a consideration when purchasing new equipment. The best and most practical approach is to reduce exposure. This can be achieved by good maintenance, improving vehicle suspensions, and damping seats. To reduce low frequency vibration, road surfaces can be smoothed.

10.3.2.6 Treatment

There are no treatments specifically for the effects of WBV, which are treated symptomatically. The best strategy is prevention.

10.3.3 Hand-arm vibration syndrome

10.3.3.1 Definitions

Since 1983, HAVS has been used as a collective term for various forms of damage to the hands and arms, suffered by workers who have worked regularly and for prolonged periods with vibrating, hand-held tools and equipment. Disease of the upper limbs associated with the use of handheld vibrating tools has been recognised for nearly a century. The many terms used for the condition include traumatic vasospastic disease, dead man's hand, Raynaud's phenomenon of occupational origin, and vibration-induced white finger. The latter is descriptive of one of the symptoms of HAVS.

10.3.3.2 Scope of potential problem

Hand-arm vibration syndrome has been described in several countries in a variety of industries, including mining and quarrying, where vibrating, hand-held, power tools are used. In South African mines, tools are used that have the potential to produce HAVS, and the incidents have been reported in gold and platinum mines (31).

Theoretically, using a rock drill, pavement breaker, or jackhammer for four hours a day would cause 50% of the machine tool operators to develop symptoms of HAVS within five years (34). It is estimated that the hands of drill operators may only be in full contact with a vibrating drill for as little as two hours a day. At such an exposure level, 50% of the machine tool operators would be expected to have symptoms of HAVS within nine years.

10.3.3.3 Sources of exposure

In the mining setting, grinders, impact hammers, jack hammers, pavement breakers, pneumatic tools, rock breakers, and rock drills are identified as potential hazards for HAVS. Additionally, the vibrations emitted by compactors, drilling machines, impact wrenches, and rotary hammer drills are a potential hazard.

10.3.3.4 Standards

The SABS has adopted ISO 28927-13:2022 and SANS 2631-5:2018 to establish the vibration value on the handle of a hand-held power tool while operating under a specific load. The dose of vibration received by a worker depends on the magnitude of the vibration and the duration of the exposure.

10.3.3.5 Aetiology

The primary cause of HAVS is working with a handheld vibrating tool with a frequency between 2–1 500 Hz. Frequencies in the 5–20 Hz range appear to be the most damaging. Prolonged exposure to vibration from using hand-held power tools and equipment leads to damage in several organ systems of the upper limb. Blood vessels, nerves, muscles, bones, and joints can all be affected. Damage to the vascular system is thought to be due to a direct effect of the vibration on the blood vessels themselves. Such damage can cause impairment to the circulation.

Damage to the nerves is also thought to be a direct result of vibration, although the swelling of adjacent tissues due to the trauma of vibration may play a role in compressing nerves. Muscular damage may be the result of nerve injury or a direct effect of the vibration. The damage to bones and joints is not well understood. Osteoarthritis and bone cysts occur in workers who are exposed to vibration from handheld tools, but the evidence that bone and joint problems are specifically caused by vibration is inconclusive. Workers who use handheld power tools are subject to other ergonomic risks factors, such as awkward postures, exertion of force, and repetitive procedures.

10.3.3.6 Symptoms

Impaired circulation gives rise to the symptoms of blanching of the fingers or parts of the hand, hence the term vibration-induced white finger. Neurological and muscular damage cause numbness and tingling in the fingers and hands. Neurological damage also causes a reduction in sensation to touch and temperature, as well as reducing grip strength and manual dexterity. The symptoms experienced from bone and joint damage are pain and stiffness in the hand, joints of the wrist, elbow, and shoulder.

There is a latent period between exposure to vibration and onset of symptoms. This period is variable and, while there are reports of symptoms occurring within a year, the latent period is typically several years. This variation is to be expected as, in addition to the varying susceptibility of individual workers, exposure will differ with occupation and the type of tool used. Factors that vary include the frequency of vibration and the time a worker is exposed daily.

The first symptom of HAVS is usually a tingling sensation in the fingers. It is often more noticeable after work has finished. Numbness may accompany the tingling. In the initial stages, if the worker is removed from the source of vibration, the symptoms may improve. As exposure continues, the symptoms are more likely to be permanent. In the next stage of the syndrome, the worker experiences periodic attacks, during which the fingers blanch or become white on exposure to cold. Initially, the blanching may be confined to the tips of the fingers, but this may progress to involve the whole finger. These attacks can last up to an hour.

When the circulation returns to the fingers, there is an intense red flush to the fingers accompanied by uncomfortable and sometimes painful throbbing. As the condition progresses, attacks can become more frequent and may occur even in warm surroundings. The attacks themselves can be painful. There is a gradual loss of manual dexterity and grip strength. In the most severe cases, blood circulation is permanently impaired, and the fingers may become dark and blue-black in appearance. In extreme cases, the fingers can become ulcerated and even gangrenous, due to inadequate circulation.

Table 10.18. Effects of hand-held vibrating tools

Affected tissues	Effect of vibration	Symptoms
Blood vessels	Direct	Blanching (white fingers), pain and throbbing; ulcers and gangrene in advanced cases
Peripheral nerves	Direct and indirect	Tingling, numbness, reduced sensation, and pain.
Muscles, bones, and joints	Direct and indirect	Pain, stiffness, and weakness

10.3.3.7 Diagnosis

The diagnosis of HAVS can be established by taking a detailed occupational and medical history, performing a physical examination, and conducting objective tests. The occupational history should put emphasis on the nature and length of past and present vibration exposure. The medical history and physical examination are crucial in the differential diagnosis of HAVS (**Appendix 10.V.3**).

Other conditions that can produce similar symptoms include intoxication, obstructive arterial disease, connective tissue diseases, hypersensitivity reactions, neurogenic disease, side effects of drug therapy (tuberculosis drugs), and trauma to the hands. During the physical examination, measurements can be made of grip strength using a dynamometer and manual dexterity using a peg board test (Purdue). Thermal esthesiometry and vibrotactile thresholds are used to assess the neurological component, and a cold provocation test is used for the vascular component.

10.3.3.8 Staging

The recommended classification method for the various stages of HAVS is the International Consensus Criteria (ICC) (35), which provides a standardised framework for assessing and classifying the condition. The ICC focuses on utilising methods with the best evidence base for assessing sensory perception and dexterity, such as vibrotactile perception thresholds and monofilament tests. Note that:

- The ICC retains the vascular and neurological components from the Stockholm Workshop Scale (SWS) but replaces the SWS for clinical and research purposes.
- The Delphi method ensures that the ICC criteria are based on expert consensus and are supported by scientific evidence.
- The ICC recommends using a blanching score, as described by Griffin, to stage vascular HAVS.
- The ICC provides a staging system for HAVS, with stages based on the severity and frequency of attacks of whiteness or loss of sensation.

10.3.3.9 Monitoring

In the SAMI, HAV is monitored using methods outlined in international Standards like ISO 5349 and ISO 2631-1. These Standards detail how to measure vibration at the point where it enters the operator's hand, often using accelerometers attached to the equipment handle. Data are collected using devices like the sound vibration analyser (SVAN958) and then analysed to assess vibration levels and potential risks of vibration-induced disorders. Chapter 16 of the MHSC’s *Handbook on Mine Occupational Hygiene Measurements*, further outlines the requirements for employers to establish and maintain systems for occupational hygiene monitoring of vibrations and medical surveillance, including risk assessments, monitoring programmes, and control measures (33)

To carry out effective surveillance, there must be a reliable method for diagnosing and staging the severity of HAVS. Currently, the SAMI uses the SWS to grade the severity of HAVS, which uses a system that separates the assessment into vascular and sensorineural (neurological) components.

Each component is graded on a scale of 0–3, with 0 indicating no symptoms related to vibration exposure and higher numbers indicating increasing severity of symptoms. The SWS also includes modifications to the scoring system, such as dividing Stage 2 into early and late stages, to better reflect the progression of neurological damage.

Monitoring schemes can identify high-risk jobs and tools. They also monitor the effectiveness of control measures and the prevalence and severity of disease. The earliest symptoms of HAVS may be completely reversible if there is no further exposure to vibration. Workers who progress to Grade 3 on the SWS should change their occupation and avoid any further vibration exposure.

10.3.3.10 Control

Control measures should primarily focus on reducing exposure. It has been reported that the early vascular symptoms of HAVS resolve if there is no further exposure to vibration. It is, therefore, important to identify early signs and symptoms of HAVS. If vibration exposure continues, then control measures should be directed at reducing vibration intensity and exposure duration.

The exposure pattern may play a role, and it is considered beneficial to have frequent rest periods, thus breaking up periods of exposure. There are also factors that adversely affect the circulatory system, such as exposure to low temperatures and tobacco smoking, which are thought to influence the progression of HAVS.

10.3.3.11 Best practice

Best practices to manage HAV in mines include:

- Vibration must be included as a factor in the design and selection of new tools and machinery.

- Use of a self-thrusting, vibration-isolating rock drill, which is a design where the drill is mechanically advanced into the rock and the operator is kept separate from the drilling process, minimising vibration transmission, is recommended. This type of drill aims to reduce noise and vibration-induced health risks for the worker, while still allowing for efficient drilling.
- Tools should be well maintained, as tools in poor repair may generate higher levels of vibration.
- Good ergonomic design and proper instruction in the use of tools can reduce the grip strength that needs to be employed, so cutting down on the transmission of vibration. A tight grip on the tool will transfer more vibration energy to the hand than will a light grip.
- The posture of the worker is important. For example, drilling on an upslope will exert more pressure and transfer vibrations more effectively to the thumbs, while drilling on a downslope will have a greater effect on the fingers.
- The vibration from tools should not exceed 2.5 m/s^2. Anti-vibration devices can be fitted to the handles of tools. A vibration-absorbing handle for a rock drill can effectively reduce hand-arm vibration, potentially minimising the risk of vibration-related health issues for operators. These handles are designed with materials and structures that dampen the vibration transmitted from the drill to the operator's hands.
- Gloves designed to provide vibration isolation are available, but their effectiveness, especially for low frequency vibration, is questionable.
- Uninterrupted exposure to vibration over extended periods should be avoided, so strategies involving job rotation should be employed. Periods of vibration-exposure work should be broken by periods of work that do not involve vibration.
- Massaging and exercising the fingers during work breaks has been suggested, to increase blood flow to the fingers.
- As cold working conditions appear to contribute to HAVS, keeping the hands and body warm helps to maintain a good blood flow to the hands. In colder countries, the wearing of gloves for warmth and the provision of warm and weatherproof clothing is recommended. In South African gold mines, where temperatures can be uncomfortably high, this is not practical advice.
- Workers should be strongly encouraged and assisted to stop smoking tobacco.

10.3.3.12 Treatment

It has been established that the pathophysiology of HAVS involves a complex interplay of vascular, neurological, and musculoskeletal issues, with vascular damage often being a prominent feature. Palliative physical therapies have been used with some subjective benefit; these include hot packs, wax baths, hot and cold baths, and infrared and microwave therapy. Drugs, which may alleviate the vascular symptoms by causing vasodilatation, have been tried, but have not been adopted routinely for treatment in other countries. The cessation of tobacco smoking is recommended, as smoking has a general vasoconstriction effect on the circulatory system. The best treatment, however, is avoidance of further vibration exposure.

10.3.3.13 Compensation

Hand-arm vibration syndrome is specifically mentioned as a compensable disease in Schedule 3 of the COIDA. See Chapter 16 of this Handbook, (Fitness to Work, Disability and Compensation).

10.3.4 Vibration exposure limits

In the SAMI, vibration exposure limits for workers are largely guided by ISO 2631-1. While there are no mandated vibration limits in the SAMI, the European Union Directive 2002/44/EC guidelines are utilised, as indicated in **Table 10.20** for WBV (36) and HAV (37).

Table 10.19. Guidelines for vibration exposure limits

	Hand-arm vibration	Whole-body vibration	Action required
Exposure action value*	2.5 m/s²	0.5 m/s²	When the exposure value is exceeded, employers must conduct a risk assessment and implement control measures
Exposure limit value**	5.0 m/s²	1.15 m/s²	Workers should not be exposed to vibration levels above these limits

*Exposure action value: a threshold for occupational exposure to vibration

**Exposure limit value: the maximum permissible level of exposure to vibration

10.4 Management of Vibration

A summary of generic actions that can be taken to manage vibration in the workplace is provided in **Table 10.21**.

Table 10.20. Generic actions to manage whole-body and hand-arm vibration in the workplace

Level of management	Action
Management	Seek technical advice from vehicle and tool suppliers as well as from experts in the field of vibration Seek medical advice from scientists and medical practitioners that specialise in vibration Develop check lists to determine employees' exposure, and to evaluate the effects of vibration on the human body Induct operators Train operators regarding operational procedures Review exposure times Develop a policy on removal from work
Actions at the workplace	Measure vibration exposure Provide appropriate equipment/ tools Maintain equipment/ tools Inform management of possible over exposures
Exposed operators	Take responsibility to use equipment/ tool correctly Avoid unnecessary vibration exposure Adjust seat properly (whole-body only) Adopt a good sitting posture (whole-body only)

	Check condition of machine/tool before using it Report defects immediately to supervisor Report symptoms to supervisor, and seek medical advice at the health clinic of the company Inform employer of whole-body and hand arm related disorders

10.4.1 Medical management of vibration

10.4.1.1 Whole-body vibration

A complete occupational and medical history needs to be taken when an operator is exposed to whole-body vibration. It is also essential to conduct a focused occupational exposure risk assessment, to fully understand the nature and characteristics of the whole-body vibration exposure.

Following this, a physical and neurological examination should be conducted, to identify a set of so-called 'red flag' conditions for underlying serious conditions (such as fracture of the vertebra or disc herniation) and the functional impact, regarding physical abilities/disabilities.

Table 10.21 provides a summary of evaluations usually included to evaluate operators exposed to whole-body vibration.

Table 10.21. General medical surveillance evaluations for operators exposed to whole- body vibration

Type of examination	Activity or required test
Physical examination	Complete and focused, including observation, palpation, functional, strength, and range-of motion tests, neurological motor and sensory evaluation, including forward flexion, hyper-extension, slump and straight leg raising tests
Laboratory test	Blood or urine (urinalysis, ESR, ANA, rheumatoid factors, complement)
Imaging studies	X-ray, CT, MRI, and myelogram
Neurological functional studies	EMG/NCS
Differential diagnoses considerations	Process of evaluating co-existing medical conditions: hormonal, metabolic, cancer, infections, psychiatric, and psychosocial conditions What are causes or aggravating factors?

ANA: antinuclear antibody test, CT: computer tomography scan, EMG: electromyography, ESR: erythrocyte sedimentation rate, MRI: magnetic resonance imaging, NCS: nerve conduction studies

10.4.1.2 Hand-arm vibration

The UK Health and Safety Executive's (HSE's) Guidance for Occupational Health Professionals indicates that health surveillance should be instituted for employees who are (38):

- Likely to be exposed on a regular basis to hand-arm exposure above the action level of 2.5 m/s^2
- Likely to be exposed occasionally above the exposure level, where the risk assessment identifies that

the frequency may pose a risk to health

- Diagnosed with HAVS, even when exposed below the action level

According to the HSE guidance note, all health professionals involved in health surveillance for HAVS are required to undergo specialist training to conduct HAVS medical surveillance. **Table 10.22** provides a summary of the HSE tiered approach for HAVS medial surveillance.

Table 10.22. Summary of the Health and Safety Executive tiered approach for hand-arm vibration syndrome medical surveillance

Tier	Activity
Tier 1: Initial or baseline assessment	Evaluation of employee before exposure to HAV, to establish a clear understanding of their health in relation to their exposure to vibration Provision of suitable information relating to HAV, before completing medical-related questionnaire Completion of self-administered questionnaire on medical history Ratification by qualified doctor of employees without symptoms suggestive of HAVS, considered fit for work exposure to HAV Identification of individuals suffering from related HAVS symptoms or diseases, who are not to be exposed to HAV
Tier 2: Annual (screening) questionnaire	Self-administered questionnaire Assisted by trained person to explain screening questionnaire and to gain confidence and cooperation of employees Personnel responsible for screening need to be trained by an occupational health professional, and need to understand health surveillance procedures and confidentiality Questionnaires to be submitted directly to occupational health service provider Employee is only referred for detailed assessment if 'yes' is answered to HAVS-related questions. Completion of questionnaire required after 12 months No need to see health professional with no HAVS-related symptoms *Note: If any HAVS symptoms are experienced during the year, they need to be reported*
Tier 3: Assessment by qualified person	Administration of a clinical questionnaire Targeted medical surveillance directed towards the vascular and neurological function in the hand and arm Assessments: limited musculoskeletal examination, grip strength, manual dexterity (Purdue pegboard) (See also Appendix 10.V.4)
Tier 4: Formal diagnosis	To be made by occupational medical doctor Reporting of diagnosed case

Tier 5:
Use of standardised tests (optional)
	Aim is to provide a quantitative assessment compared to 'normal' data (not a confirmation of HAVS, as doctor needs to make the diagnosis)
	Proposed tests (see also Appendix 10.V.4):
	• Vascular tests:
	  ○ Finger rewarming after cold provocation test (CPT)
	  ○ Finger systolic blood pressure test (FSBP)
	• Sensorineural tests:
	  ○ Vibrotactile perception threshold (VPT)

	o Thermal (temperature) perception threshold (TPT)

10.4.2 Medical implications of vibrations

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10.4.2.1 Whole-body vibration

Due to the complex nature of whole-body vibration, operators may report non-specific health complaints and symptoms that involve the musculoskeletal system and various other organ systems. **Table 10.23** summarises the most reported complaints and systems that may be linked to specific organ systems (39).

Table 10.23. Common non-specific health-related complaints and symptoms reported by operators exposed to whole-body vibration

Organ system	Complaint/symptom
Orthopaedic and neurological system	Localised or radiating pain, discomfort, numbness, tingling, loss of feeling and muscle control in spine or extremities
Gastro-intestinal system	Nausea, vomiting and indigestion, flank pain (renal), hemorrhoids-related seating discomfort
Female reproductive organs	Localised pain, discomfort, irregular periods (concern for pregnancy)
Prostate	Burning sensation, urgency
	Heamaturia, prostate enlargement/PSA marker elevation (concern for cancer)
Peripheral veins	Leg pain, leg weakness, poor circulation
Cochlea-vestibular system	Vertigo

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10.4.2.2 Hand-arm vibration

Reported clinical effects on the hands of workers exposed to HAV include symptoms related to pathologies of the peripheral vascular system, peripheral nervous system, muscles, and other soft and hard tissues of the hand and arm. The following table provides a summary of the various systems, with associated signs and symptoms as articulated by the HSE (40).

Table 10.24. Signs and symptoms related to hand-arm vibration exposure

System	Signs and symptoms
Neurological	Numbness and tingling in the fingers Reduced sense of touch and temperature Difficulty to feel and to work with small objects
Vascular	Episodic finger blanching triggered by exposure to cold – vibration white finger/dead finger/dead hand. Note: Condition is caused by vibration, but it does not precipitate the symptoms Painful red throbbing fingers (reactive hyperaemia) following initial blanching (vasospasm), due to either spontaneous restoration of circulation or after rewarming

	During attack, complaints of numbness, pain, and cold, and reduced manual dexterity Initial effects only in tips of affected fingers, but spreading up the finger with repeated exposure Frequency of attacks increase with progression of the condition
Muscular and soft tissue	Joint pain and stiffness in the hand and arm Reduced grip strength

HAV: hand-arm vibration

Note: Carpal tunnel syndrome can also be caused by HAV exposure. Hand-arm vibration syndrome may also have an impact on social and family life, as attacks may present during activities such as washing the car, participation in outdoor sport activities, and even performing fine dexterity tasks such as fastening buttons on clothes.

10.4.3 Women in mining vibration considerations

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The MCSA, and other organisations like the Women in Mining South Africa, are actively working to increase women's participation and improve their working conditions in the SAMI. Although initiatives focus on attraction, retention, and development of female talent in mining, safety concerns have been raised related to the general effects of vibrations on women in mining (WiM).

Studies have shown that vibrations, as well as the operating of heavy vibrating equipment and machines, such as locomotives, winding engines, rubber dozers, and dump trucks, are not good for women, even if they are not pregnant (41). Vibrating equipment tends to affect women’s menstruation cycles and even causes miscarriage in cases of pregnancy. Additional literature analyses of the effects of occupational vibration on the female reproductive system and function, by Penkov (2007) (42) and Seidel (1993) (43), showed that exposure contributes to the pathogenesis of disorders such as decrease in uterine blood flow, menstrual disturbances, anomalies of position, abortions, and stillbirths. It is, therefore, advisable that considerations be made regarding women’s exposure to vibration-intense job types.

10.4.2.3 Exposure control and management

To reduce the risk of vibration injuries, mines must implement a multi-faceted management approach that significantly reduces the risk of vibration-related injuries, creating a safer environment for their employees. Management measures include:

- Engineering controls – including isolating the vibration at source, using low-vibration tools, continuously maintaining equipment, and optimising workstation designs to minimise awkward postures and reduce strain on the body
- Administrative controls – including reducing the amount of time workers spend using vibrating tools or on vibrating surfaces, implementing job rotation to distribute vibration exposure among different workers
10 and prevent prolonged exposure for any individual, encouraging regular breaks to allow hands and arms to recover from vibration exposure, and educating workers about vibration hazards, proper tool usage, and the importance of reporting symptoms
- Personal protective equipment – ensuring workers use gloves designed to absorb and reduce vibrations, and ensuring workers are properly dressed to prevent cold temperatures, which can worsen vibration-related injuries
- Health surveillance – implementing health surveillance programmes to monitor workers for early signs of vibration-related injuries, and providing appropriate treatment

- Gender-specific considerations – ensuring that tools and equipment are suitable for workers with smaller hand sizes, as this can impact grip and force application, potentially increasing vibration exposure

Ergonomic factors should also be considered, especially in relation to posture and grip strength, which can vary between individuals. There should also be awareness programmes among both female and male workers about the potential risks of vibration, and the importance of following safety procedures.

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Appendix 10.N.1 Education, Motivation, and Training

Tables 10.N.1a, **10.N.1b**, and **10.N.1c** summarise occupational noise risk management learning outcomes for targeted groups.

Table 10.N.1a. Target groups and relevant learning topics

Target group and relevant learning topics			
Employers and senior managers	**Line managers and supervisors**	**HCP management and HSCs**	**Workers**
Formulation of risk management systems, procedures, and implementation strategies Consultation and communication techniques Negotiation and motivational techniques Training and instruction requirements Coordinating the implementation of risk management measures Evaluating results	Contributing to the development and implementation of risk control measures in own area of responsibility Informing and motivating workers, regarding risk control measures and revised work procedures	Evaluation criteria for risk management systems, procedures, and implementation strategies Requirements for training content, informational, motivational, and instructional materials Promotion of communication between management and workers	Evaluating potential risk control measures for own workplace Implementation requirements for measures adopted Consulting with co-workers, supervisors and HSRs, regarding control measures and remaining concerns

HCP: hearing conservation programme, HSC: health and safety committee, HSR: health and safety representative

Table 10.N.1b. Relevant skills and knowledge for given target groups

Employers, senior managers, line managers, and supervisors	Workers
Required provisions for risk management and control measures in employer's CoP Comprehensive knowledge of equipment and processes requiring noise control treatment and their prioritisation in terms of risk assessment results Sources of appropriate expertise; awareness of technological developments and recent research findings Selection criteria for risk management systems, procedures, and implementation strategies. Development of appropriate risk management systems, procedures, and administrative mechanisms, such as flow-charts, proformas, and record- keeping systems Consultation during development of systems and procedures that are based on engineering, administrative, and personal protection strategies Formulation of evaluation criteria Knowledge of training, instruction, and supervision requirements and of special needs Informational and motivational techniques for communicating risk management procedures and implementation strategies	Required provisions for risk management and control measures in employer's CoP Prevailing risks and requirements for control measures in own workplace Advantages and disadvantages of potential risk control measures Selection criteria for emission and exposure reduction measures Evaluation criteria for control measures that are adopted Awareness of mechanisms and procedures for participating in the selection and development of risk control measures for own workplace

CoP: Code of Practice

Table 10.N.1c. Key performance indicators

Basis of key performance indicators relevant to given target group	
Employers, senior managers, line managers, and supervisors	**Workers**
Implementation of control measures to reduce noise emission and exposure levels Inclusion of provisions for noise control in equipment operating and maintenance procedures Incorporation of noise emission limits into equipment maintenance procedures and procurement criteria Effectiveness of consultation with workers, HSRs, and line managers/supervisors Provision of enabling information, motivation, and support, including training, instruction, and supervision Implementation of procedures for ongoing monitoring, evaluation, and revision of risk control measures Appropriateness of actions taken on basis of findings from HPD compliance; occupational hygiene monitoring, and medical surveillance Appropriateness of HPDs made available for all required applications, and provision for special needs Adequacy of resources allocated Achievement of targets for reducing noise emission, exposure levels, and incidence of NIHL	Level of participation in the consultation process Extent of contribution to development and implementation of risk control measures in own workplace Usefulness of feedback to line managers/supervisors and HSRs, regarding effectiveness of risk control measures and any remaining concerns Level of compliance with procedures for reducing noise emission and risk during machinery operation Extent of application of noise reduction criteria and emission limits during maintenance procedures Level of compliance with risk control procedures, including proper use of HPDs in designated areas and during noisy operations Level of participation in educational, training, and motivational programmes

HPD: hearing protection device, HSR: health and safety representative

Appendix 10.N.2 Noise Control Engineering

Table 10.N.2 summarises a variety of noise problems, the treatments applied, and their effect on noise level. In some cases, other effects are also considered, such as impact on performance or maintenance requirements. Noise reductions are not quantified in all examples, such as where specific details of the machinery, circumstances of its installation/operation, and the NCE treatment constitute the principal determinants of achievable reductions.

Table 10.N.2 Examples of engineering measures to control noise

Source	Nature of problem	Treatment	Effect/reduction
Boiler exhaust	High-pressure steam vented through large-diameter pipe, producing elevated level, low-frequency noise	Fit a perforated cone exhaust diffuser to existing vent pipe, splitting single exhaust jet into several smaller ones to reduce velocity and increase frequency	Overall reduction up to 40 dB with no loss in performance
		Install perforated, absorbent attenuator to reduce higher frequency noise from diffuser	Attenuator requires some maintenance, such as. periodic replacement of absorbent fill material
Coal processing screens	Screening process and machinery drive components produce broadband noise at high intensities	Install resilient screen components	Resilient screen components: 3 dB
		Provide acoustic enclosures around screens	Acoustic enclosures: 7 dB
		Install acoustic barrier curtains	Barrier curtains: 5 dB
		Provide acoustic enclosure for drive components	Drive enclosure: 2 dB
Crushing and milling machinery	Crushing/milling of material and machinery drive components generate high levels of low-frequency noise	Install rubber lining in mills	Lining reduces level by 5 dB, but periodic replacement needed
		Install large, high-density acoustic barrier panels around/above crushing and milling machinery, or provide acoustic encloses	Barrier panels reduce noise by 6 dB, and enclosures provide reductions of up to 8 dB
		Provide isolation-mounted acoustic enclosure for operators	Isolated operator enclosure reduces exposure by 17 dB

Source	Nature of problem	Treatment	Effect/reduction
Diesel-powered machinery	Engine, transmission, and cooling fan cause excessive noise in cabin and area of operation	Exhaust silencer; vibration-damping of engine, transmission, and cabin mountings/interfaces; acoustic treatment of engine compartment, cooling fan, and operator cabin	Reductions of 3–20 dB in cabin and 2–5 dB in area of operation, depending on type of machinery and combination/extent of noise control engineering treatments
Pneumatic rock drill	High-velocity exhaust creates turbulence and noise in surrounding air; drill steel vibration and impact between mechanical parts produces additional noise	Fit manufacturer's silenced cylinder or exhaust muffler	Exhaust silencing: 7–10 dB reduction, but penetration rate reduced by 10–30 %
		Incorporate anti-vibration decoupler fitting into drill steel near chuck	Decoupling steel from machine: 3–5 dB reduction
		Enclose drill steel in a collapsible bellows-type sheath, and/or damp steel with anti-vibration coating	Enclosing/damping drill steel: 2–5 dB reduction
		Damp machine casing with an anti-vibration coating	Damping drill casing: 2–3 dB further reduction
Fan noise caused by turbulence at intake	Obstacle near fan, either a reduction in duct cross-section, a bend, or a regulating valve, causing turbulence, vibration, and noise at fan intake	Re-position fan or obstacle; decrease sharpness of bend to allow turbulence to dissipate before fan intake; install flow guides ahead of fan intake	Reduced turbulence lowers vibration in fan and ducting, reducing noise and mechanical stress on both
Fan noise transmitted by ducting	Ducting transmits noise from ventilation or extraction fan to areas far removed from source	Introduce changes in ducting's cross-sectional size and add side branches to reflect some transmitted noise back towards source for reactive attenuation	Reduced noise transmission, depending on details of original ducting and nature of modifications
		Changes should be to an increased duct size, to allow expansion of air into what will act as a reactive silencer, and to prevent turbulence	Reactive attenuation can supplement or replace attenuator
		Install absorbent panels in ducts	Further reductions in transmitted noise

Source	Nature of problem	Treatment	Effect/reduction
Large fan transmitting noise to distant locations	Low-frequency noise produced at high intensity levels, creating a noise problem at distant locations	Increase number of fan blades and reduce rotational speed using an electronic speed controller, so as to maintain required fan performance	Frequency of noise increased in proportion with number of blades added, allowing greater attenuation with distance; lower fan speed reduces motor noise
Turbulence in conveyance pipes generates noise	Sharp bends, closely spaced control valves and internal accumulations of scale create turbulence in the flow of material being conveyed	Install gentler bends in piping to reduce turbulence	Reduced turbulence and noise
		Increase distance between control valves to allow settling of turbulence before next valve	Reduced loading of pump and improved performance
		Control or periodically remove accumulations of scale	Improved flow and reduced maintenance for control valves
Turbulence around in-line fluid-regulating valve generates noise	Small valve seat causes high flow velocity and turbulence around seat	Install valve with a larger seat	Reductions in turbulence, vibration and noise, better valve performance and service life
	Indirect fluid path and sharp edges inside valve add further turbulence	Install valve with more direct flow path and smoother internal edges	Reduced load on pump, with less maintenance and longer service life
	Vibration is transferred to pipe, causing structure-borne noise	Install a pressure reduction insert ahead of valve to prevent cavitation downstream, and damp pipe supports to decouple them from building's structure	Reductions in fluid turbulence and structure-borne noise transmission through building
Radiated noise	Large, unbroken vibrating surfaces efficiently radiate energy into the surrounding air as noise	Replace flat, unbroken panels with perforated/ expanded metal panels to reduce surface area	Reduced radiation of energy into surrounding air
		Increase the number of edges around radiating surfaces to equalise pressure differences	Some self-cancellation of noise around edges of perforations

Source	Nature of problem	Treatment	Effect/reduction
Structure-borne plant noise	Noise from a refrigeration plant or compressor is directly transmitted into structure of the building, and also throughout building by material conveyance pipes	Fit spring-damped machine mountings or, preferably, install an isolated machinery foundation	Noise previously transmitted throughout the facility is confined to immediate area of the source
		Damp pipe supports and brackets to decouple pipes from building's structure	
		Install flexible pipe sections between plant and its reticulation system	
		Supply power to plant by flexible cabling without steel conduit	Additional measures may be required to protect personnel near source
Vibrating source	Large panel in contact with machinery is vibrating, radiating elevated levels of noise into the surrounding area	Isolate/separate machinery from panel	Considerable noise reduction, depending on the size/emission level of machinery, and the size/density of panel
		Damp panel or replace with perforated or expanded metal panel to allow self-cancellation of noise	
		Reduce size/surface area of panel	
Wide drive belt	A single, wide drive belt produces low-frequency noise at high levels	Replace the single, wide belt with a suitable number of narrower belts, to allow self-cancellation of noise at gaps and edges between belts and a reduction in belt surface area	Noise reductions of up to 10 dB attributable to self-cancellation of noise and reduced transmission from belt surfaces
Workshop with high levels of low- and high-frequency noise	Several machines, large and small, collectively cause elevated levels of broadband noise throughout the workshop, even at locations distant from any source	Suspend vertically oriented, high-density panels from ceiling, using taller, higher, and denser panels for low frequency noise	Vertical panels absorb sound on both sides
		Where vertically oriented panels will cause obstructions, suspend horizontal panels as far below the ceiling as possible	Horizontal panels are more effective if positioned away from ceiling; noise near individual sources unchanged, but overall levels reduced by up to 10 dB

Source	Nature of problem	Treatment	Effect/reduction
Pneumatic grinder	High-velocity exhaust air vented through grinder handle, causing turbulence in surrounding air and noise	Fill handle with steel wool packing to diffuse exhaust air and reduce exit velocity	Noise reduction of 15–20 dB
Pneumatic scaling and cleaning gun	A simple, single-jet delivery nozzle generates excessive turbulence and noise at outlet	Replace single-orifice nozzle with compound nozzle for a lower-speed annular air stream around high-speed mainstream	Total noise reduction of up to 20 dB
		Install exhaust diffuser for a smoother transition of the mainstream into surrounding air	
Sandblasting bay	Noise from unenclosed source is transmitted throughout workshop	Build insulated enclosure around sandblasting bay, with heavy lead- and rubber-laminated curtains for access	Noise in immediate vicinity reduced by up to 20 dB, but operator will still require protection
Several small machines in workshop contribute to excessive levels of high-frequency noise	High-frequency noise from several small bench-mounted machines is reflected by walls and ceiling into adjacent areas	Install a lightweight absorbent screen near each machine at a relatively elevated position	Screen reduces high-frequency noise at operator's position
		Cover ceiling with absorbent panels to prevent reflection into adjacent areas	Ceiling treatment controls propagation into adjacent areas
		Enclose each source with absorbent cabinet to contain noise and reduce levels at operator's position, but avoid restricting access	Enclosing individual sources reduces levels at operator positions and throughout area

Table 10.N.3 Use of Octave-band method in calculating noise reduction for hearing protection device users

	Octave-band centre frequency (Hz)							*Sound level dB(A)
	125	250	500	1 000	2 000	4 000	8 000	
1) Linear/ unweighted SPL measured in workplace	85.0	87.0	90.0	90.0	85.0	82.0	80.0	
2) A-weighting SPL in (dB)	- 16.1	- 8.6	- 3.2	0.0	+ 1.2	+ 1.0	- 1.1	
3) A-weighting SPL in dBA [1)–2)]	68.9	78.4	86.8	90.0	86.2	83.0	78.9	93.5
4) HPD mean attenuation (dBA)	27.4	26.6	27.5	27.0	32.0	44.0	42.2	
5) Standard deviation x2 (dBA)	7.8	8.4	9.4	6.8	8.8	7.0	10.4	
6) HPD effective attenuation in dBA [4)–5)]	19.6	18.2	18.1	20.2	23.2	37.0	31.8	
7) Estimated effective SPL in dBA [3)–6)]	49.3	60.2	68.7	69.8	63.0	46.0	47.1	73.0

HPD: hearing protection device, SPL: sound pressure level

*Sound level, in A-weighted decibels, is the logarithmic sum of the seven octave-band SPLs in same row 10

Source: Adapted from Berger (2003) (44)

Appendix 10.N.4 Medical Surveillance/Audiometry

Audiometric test procedures are detailed in the two sub-sections below. The use of test results to evaluate hearing status and eligibility for compensation is outlined in section 10.N.4.3 below.

10.N.4.1 Sequence of test frequencies

The preferred sequence of audiometric test frequencies for each ear in succession, starting with the better ear, is indicated in **Table 10.N.4.1**.

Table 10.N.4.1 Preferred sequence of audiometric test frequencies

Order of audiometric test frequencies	
1) 1 kHz	6) 8 kHz
2) 2 kHz	7) 500 kHz
3) 3 kHz	8) 250 kHz
4) 4 kHz	9) 125 kHz
5) 6 kHz	10) Repeat 1 kHz (mandatory for first ear only)

10.N.4.2 Determining hearing threshold levels

Procedures for determining the hearing threshold level for each test frequency are detailed in Steps 1 through 5, below:

1. Starting with the better ear (determined by questioning the subject or referring to previous results), present a 1-kHz test signal at a level that is 10 dB lower than that at which a response was observed during the familiarisation phase.
2. After each failure to respond to the test signal, increase the decibel hearing level (or loudness) by 5 dB, until a response is obtained.
3. After each response, decrease the level by 10 dB and present a signal. If no response is obtained, then increase the level in 5-dB increments until the subject responds. Repeat this process until three responses are obtained from five presentations at the same level and record that value as the hearing threshold level for 1 kHz.
4. Repeat Steps 1 to 3 for the same ear at each test frequency, until a hearing threshold level has been recorded for each.
5. Repeat Steps 1 to 3 at 1 kHz for the first ear. If the second result for 1 kHz agrees with the initial result to within 5 dB, then proceed to the second ear, repeating Steps 1 to 4, and following the same sequence of test frequencies (i.e. 1 kHz to 125 kHz in Table 10.N.4.1, as applicable, but without repeating the threshold determination for 1 kHz).

6. If a variation of 10 dB or greater is observed between the two thresholds determined at 1 kHz for the first ear, then retest that ear at all frequencies and in the same order (i.e. 1 kHz to 125 kHz, as applicable), to obtain two results for 1 kHz that are within 5 dB. If inconsistencies of 10 dB or more are still apparent after the second confirmation attempt (third determination), then the subject should be referred to an OMP for medical opinion and consideration of the possible need for an audiologist/specialist evaluation.

10.N.4.3 Evaluation of hearing status and eligibility for compensation

Workers' Compensation Commissioner Instruction 171 stipulates an increase in PLH of 10% or more, relative to the employee's baseline audiogram, as indicative of a possible compensation claim. In terms of the COIDA (section 68(2)), the employer is obliged to inform the Compensation Commissioner or relevant mutual association of such cases within 14 days, irrespective of any agreement or dispute regarding their merit or validity. Tables for determining PLH attributable to hearing losses at 0.5; 1; 2; 3, and 4 kHz may be obtained from the Compensation Commissioner.

Appendix 10.V.1 Regulations and Standards for Vibration

SANS 2631-1:2017 and SANS 2631-2:2018 – Evaluation of human exposure to whole-body vibration

- Give comfort levels for WBV
- Define methods for the measurement of periodic, random, and transient WBV
- Indicate the principal features that combine to determine the degree to which a vibration exposure will be acceptable

SANS 10450-1:2017 – Guide to measurement of WBV and reported shock

ISO 8041 – Human response to vibration: measuring and instrumentation

- Gives the standards for measuring equipment
- COIDA Schedule 3
- Specifically mentions HAVS

ISO 5349-1:2001 and ISO 5349-2:2001 – Mechanical vibration: guidelines for the measurement and assessment of human exposure to hand-transmitted vibration

ISO 10819 – Mechanical vibration and shock. Hand-arm vibration

- Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand

ISO 28927-13:2022 – Hand-held portable power tools. Measurement of vibration at the handle. Part 3. Rock drills and rotary hammers

- Specifies a laboratory method of measuring vibration at the handle of hand-held power-driven rock drills and rotary hammers

ISO 8041-1:2017 – Performance and tolerance limits for instruments used to measure human exposure to vibration

ISO 8041-2:2021 – Minimum requirements for personal vibration exposure meters (PVEMs)

Appendix 10.V.2 *(Source SIMRAC Report GEN 503)*

Table 10.V.2 a Vibration levels of commonly used hand-held equipment in the South African mining industry

Type of equipment	Average maximum weighted acceleration measured in m/s^2
Pneumatic rock drills	24
Hydraulic rock drills	24
Pavement breakers and jack hammers	19
Pneumatic grinders	1.3
Electrical hammer drills	8.8
Pneumatic wrench	10
Drill sharpening machine	2.5
Drill re-collaring machine	5.1
Hand-held compactor	13

Appendix 10.V.3 Medical Examination and Tests for Hand-Arm Vibration Syndrome

10.V.3.1 Clinical tests

The medical examination is performed by a doctor, and includes the following:

i) Examination of the hands, fingers, and upper body for callosities, scars, trophic changes, and any skeletal abnormalities
ii) Taking blood pressure on both arms
iii) Allen's test – demonstrates the integrity of the radial and ulnar arteries of the hands
iv) Tinel test – used to elicit symptoms of carpal tunnel compression
v) Phalen's test – used to elicit symptoms of carpal tunnel compression
vi) Adson's test – detects obstruction to the arterial flow in the arm at the level of the neck
vii) Purdue pegboard test – assesses the dexterity of the hands and fingers
viii) Grip strength test – assesses the muscle strength of the hands, using a dynamometer

10.V.3.2 Objective tests for hand-arm vibration syndrome

10.V.3.2.1 Thermal aesthesiometry assesses nerve damage

This test measures temperature perception. The index and little fingers of both hands are tested. The fingertip is placed on a metal plate, where the temperature is varied. The response button is pressed every time a change in temperature is detected. From these responses, the cold and hot thermal perception thresholds are calculated. The difference between the cold and hot thermal perception thresholds is called the thermal neutral zone (TNZ), which is the range of temperature that the subject cannot detect. The more damage to the nerves of hands and fingers, the larger the TNZ. The software for thermal aesthesiometry has a built-in safety feature, which returns the temperature to the reference temperature (32.5 °C) if the response button has not been pressed and the temperature reaches 55 °C or 5 °C. The hardware has an in-built thermostat, which automatically cuts out the heat if the temperature reaches 57 °C.

10.V.3.2.2 Vibrotactile threshold test to assess nerve damage

This test measures vibration perception. The index and little fingers of both hands are tested. Two vibration frequencies (31.5 Hz and 125 Hz) are applied to a probe. The fingertip is placed on the probe and a response button is pressed every time vibration is felt. From these responses, the vibration perception threshold is calculated. The more damage to the nerves of hands and fingers, the higher the vibration perception threshold. The two vibration frequencies used in this test are not harmful.

10.V.3.2.3 Cold provocation test to assess damage to blood vessels in the hands

Both hands are tested. Thermocouples are attached to the fingertips. The hands are gloved and immersed in a 15 °C water bath for five minutes. On removal from the water bath, they are allowed to rewarm at room temperature for ten minutes. During this time, the finger skin temperature is measured. The time taken by the fingertip to rewarm by 4 °C is recorded. The more damage to the blood vessels, the longer it takes for the fingertips to rewarm. The temperature in the water bath is thermostatically controlled.