

# Noise exposure in gold miners: utilising audiogram configuration to determine hearing handicap

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## ABSTRACT

The objective of the study was to investigate the relationship between the audiogram configuration and its calculated Percentage Loss of Hearing (PLH), and the experience of hearing handicap in noise-exposed gold miners. The latter was measured using a translated Hearing Handicap Inventory for Adults. NIHL audiograms were categorised into five different patterns based on their configurations. A contingency table of the audiograms, the PLH and measures of hearing handicap was constructed. All participants, no matter what their audiogram configurations and degree of hearing loss as measured by the PLH, experienced significant handicap as a result of their hearing loss, including the group where most of the audiogram thresholds were within normal limits. The study highlights the need for awareness of appropriate rehabilitation and counselling in this population and offers a model for quantifying the effects of NIHL that takes into account the effect of the hearing loss on the quality of life as well as the audiological results.

## INTRODUCTION

Quality of life depends on the ability to communicate, which is dependent on the ability to understand spoken communication, which is in turn dependent on the ability to hear. Hearing loss is therefore a primary cause of the experience of a hearing handicap and a reduction in the quality of life. Noise-induced hearing loss (NIHL) is one of the forms of hearing loss which drastically reduces millions of worker's quality of life the world over.<sup>1</sup>

## NIHL AND ITS IMPACT ON QUALITY OF LIFE

NIHL is known to be a high-frequency hearing loss and in clinical practice can present in a variety of configurations and degrees. NIHL is characteristically a progressive permanent sensori-neural hearing loss which develops as a result of exposure to high levels of noise known to damage the outer hair cells (OHCs) of the cochlea.<sup>2,3</sup> The function of the OHC is frequency selectivity and the selection of important stimuli, which assists the listener to exclude background sounds.<sup>3</sup> NIHL results in sounds being heard in an abnormal way and the hearing loss results in reduced hearing thresholds and reduced supra-threshold functioning and speech processing.<sup>2,3,4</sup> People with high-frequency hearing loss are usually able to understand speech well in a quiet environment but experience significant difficulty in the presence of background noise or when a number of speakers are taking part in a conversation.<sup>2,3,4</sup> The degree of hearing loss has a direct influence on the perception and processing of speech. The ability to discriminate the phonetic properties of speech requires that hearing across all frequencies of speech must be intact.<sup>5,6,7</sup> The impact on a person's quality of life may not only be audiological, as noise and NIHL have also been documented as having psychosocial/non-auditory effects.

Non-auditory effects of NIHL have been noted as being non-specific stressors such as feelings of anxiety, reduced speed of eye movements resulting in focus difficulties and visual field reduction, increased corticosteroids, narrowing of blood vessels and increased blood pressure, vertigo, nystagmus, increased fatigue, and increased effort to communicate. Other problems that are commonly experienced in NIHL victims are recruitment and tinnitus.<sup>7,8,9,10</sup> NIHL as seen above can have a negative impact on the quality of life of a victim. NIHL is predominantly caused by occupational noise exposure and can therefore also compromise the safety and health of workers.<sup>11,12</sup>

## NIHL IN SOUTH AFRICAN MINERS

Protecting the health and safety of South African miners is essential as the country is a rich producer of gold, platinum and many other minerals and employs thousands of workers in the industry. The NIHL caused by high levels of noise exposure in the gold mining industry in South Africa results in a lower experience of quality of life for many South African miners. Legislation governing the measurement of hearing levels as a Percentage Loss of Hearing (PLH) and the financial compensation for the audiological effect of NIHL receives high priority in the gold mining industry.<sup>13,14</sup> The financial compensation for NIHL, however, does not acknowledge the impact of NIHL on the quality of life of workers.

## MEASUREMENT OF HEARING HANDICAP

The reduction in quality of life, or hearing handicap, cannot adequately be measured by pure-tone audiometry,<sup>15,16</sup> and has been investigated with various measurement tools to supplement the information found on an audiogram.<sup>17</sup> The quantification of the experience of handicap has been shown to be facilitated by the Hearing Handicap Inventory for the Elderly (HHI-E)<sup>15</sup> and the alternative format, Hearing Handicap Inventory for Adults (HHI-A),<sup>16,18</sup> where hearing handicap is expressed in a percentage.

## RATIONALE FOR THE STUDY

Literature reveals that very little is known about the relationship between hearing handicap and the audiometric configuration or degree of hearing loss,<sup>17</sup> as the latter is not necessarily indicative of the experience of hearing handicap and therefore of reduction in quality of life. The demonstration of an association between the audiogram configuration (and the PLH) and the experience of handicap in a NIHL population could offer occupational audiology practice the potential of a model to quantify such a relationship.

## PURPOSE OF THE STUDY

To conduct a preliminary exploration of the relationship between audiogram configurations as expressed in PLH and the experience of hearing handicap in noise exposed gold miners.

## METHODOLOGY

### Research design

A cross-sectional survey of noise exposed goldminers who had attended a private audiological practice in the North West Province

of South Africa and their records were used for this study. The practice is geographically situated in a gold mining area and the caseload was predominantly gold miners during the period 1992 to 2003.

### Selection criteria

The following selection criteria were applied:

- Exposure to occupational noise in the gold mining industry. Records were of gold miners referred to a private practice for diagnostic audiology for possible NIHL compensation.
- No otological history of middle ear pathology, ototoxic medication or hereditary hearing loss. The impact of NIHL on the experience of hearing handicap was the focus of the study requiring controls for other possible causes of hearing loss.
- Bilateral sensori-neural hearing loss recorded on a diagnostic audiogram in the practice. NIHL characteristically affects the cochlea bilaterally and results in a sensori-neural hearing loss.
- Telephonic contact details on record. This would facilitate the ethical requirement of informed consent and data collection from the questionnaire.

### Sampling and sample size

All 1471 participants whose records met the selection criteria were approached telephonically to participate in the study. Of these, 684 participants could not be contacted telephonically and four refused to participate. A total of 783 questionnaires were sent to consenting prospective participants, of which 339 (23,05% of the population) completed questionnaires were returned within the time frame set by the researcher.

### Research tools

#### Hearing handicap questionnaire

The Hearing Handicap Inventory for Adults (HHI-A)<sup>16</sup> was translated into Afrikaans by the principal researcher, a mother-tongue Afrikaans speaker, as the private practice where the records were sourced and the participants were found to be predominantly Afrikaans speaking. The HHI-A is reported in the literature to be useful because of the short easily interpreted nature of the questionnaire that also has good internal validity and test retest reliability.<sup>15,16,17,18,19</sup> The questionnaire (as shown in Table 1) probes the type of handicap experienced for everyday life situations such as group discussions and use of the telephone. It also investigates the impact the hearing loss has on the person's self-image and the limitations on their lifestyle that result from the NIHL.

A pilot study with 10 participants was conducted to ensure that the translated adapted version could be easily used by participants. The findings of the pilot study indicated the inability of the participants to answer question eleven (Do you experience difficulties hearing in theatres or movie theatres?) as their social habits did not include theatres or movie theatres. However, they consistently said: "But I do have difficulties in church". The standardised version of the questionnaire was therefore adapted by replacing question eleven with question eleven from the HHI-E (Do you experience difficulties hearing in church services?).<sup>15</sup>

The main sections of the questionnaire are summarised in Table 1.

### Diagnostic audiogram and case history form

The pure tone air conduction thresholds of all the participants for 250 to 8000 Hz of the better ear were included in the study. These thresholds were used as NIHL is known to be a bilateral, sensori-neural, symmetrical hearing loss<sup>3,5,7</sup> and no significant difference between ears nor between air and bone conduction thresholds were expected. The literature is inconclusive as to which ear is more predictive of hearing handicap and a clinical decision was made to use the ear with better thresholds.<sup>5,8</sup> The presenting difficulty at the time of the diagnostic audiogram as recorded on the case history form was also noted in the raw data.

### Data collection

1. Once telephonic consent was obtained, a questionnaire numbered with a study number and full instructions on how to complete and return it was posted to the participant. Completed questionnaires returned by the agreed-upon cut-off-date were used in the study.

2. The audiogram from the audiological record of each participant who had returned a completed questionnaire was coded with the same study number and recorded on a Microsoft Excel spreadsheet.

### Data analysis

The completed questionnaires were coded and scored according to the scoring method prescribed by the authors.<sup>16</sup>

The scoring was as follows:

Four points for every "yes" answer;

Two points for every "sometimes" answer; and

One point for every "no" answer.

The summed scores were out of 50 points and were doubled to reach a percentage. The interpretation of the scores is based on the following categories as specified by the authors<sup>16</sup>:

- 1–16% No experience of hearing handicap;
- 17–42% Mild experience of hearing handicap;
- 42%+ Significant experience of hearing handicap.

Audiograms were grouped according to the degree of hearing loss and the configuration pattern as follows:

Group 1: 250 Hz – 2 kHz Normal, 3–8 kHz Mild;

Group 2: 250 Hz – 2 kHz Normal, 3–8 kHz Moderately-severe;

Group 3: 250 Hz – 1 kHz Normal, 2 kHz Moderate, 3–8 kHz Moderately-severe;

Group 4: 250 Hz – 500 Hz Mild, 1-2 kHz Moderate, 3–8 kHz Moderately-severe;

Group 5: 250 Hz – 1 kHz Moderately-severe, 2–4 kHz Severe, and 6–8 kHz Profound.

The hearing handicap scores of the participants in each of the audiogram configuration groups were averaged. In addition, the PLH was calculated for each audiogram configuration group using the averaged hearing thresholds at frequencies 0.5, 1, 2, 3, and 4 kHz as the input values in the PLH calculation tables.<sup>13</sup>

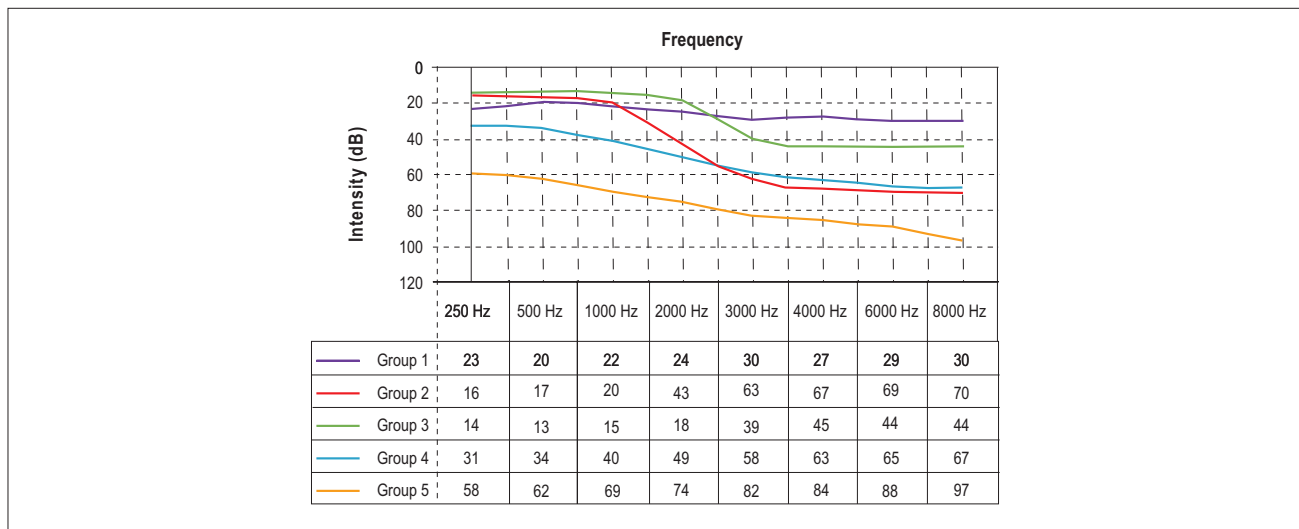
The presenting problem, as noted on the case history form, was categorised and the most prevalent for each audiogram configuration group was allocated as the presenting problem for that group.

## RESULTS

Figure 1 graphically depicts the averaged pure tone thresholds of

Table 1. Hearing Handicap Inventory for Adults (HHI-A)<sup>29</sup>

Category of hearing handicap	Number of questions	Area probed by questions	Examples of questions
Situational hearing handicap	12 questions	Investigates hearing handicap in different everyday life situations	Group discussions, use of telephone, complex listening situations
Emotional hearing handicap	13 questions	Investigates hearing handicap with reference to emotional well-being of the affected person	Impact on self-image, frustrations experienced, limitations on lifestyle as a result of hearing loss



**Figure 1. Averaged pure-tone thresholds in decibels of noise from better ear audiograms of exposed gold miners**

the better ears of the noise-exposed participants in this study. The five groups of audiograms based on the degree of hearing loss and configuration pattern are seen on the audiogram and their average pure tone threshold levels are listed in the legend.

A contingency table (Table 2) was created using the configuration patterns of the audiogram (expressed as a PLH) and the extent to which the participants experienced a hearing handicap both from a situational and an emotional perspective. In the same table, the degree of hearing handicap experienced is also linked to the presenting difficulty that was noted in the case history during the assessment. All groups reported a significant degree of hearing handicap (i.e. a score higher than 42%).

## DISCUSSION

A limitation of the study was the small sample size and the fact that selection bias may have been present. Despite this, some unexpected findings, shown in Table 2, require closer inspection. Participants whose audiogram configuration was classified according to the first pattern revealed the most unexpected results. The audiogram configuration and description are unremarkable as a very mild, early noise-induced hearing loss exists, with all important speech frequencies (500, 1000 and 2000 Hz) well within normal limits. However, the results indicate that this group

with an averaged PLH of 4.1%, which is not compensable under South African legislation, experiences a significant hearing handicap (47.8%) and thus a significant decrease in the quality of life.

The results of Group 2 are also surprising, as they appear to experience slightly less hearing handicap than the mild hearing loss group (Group 1), despite the higher PLH (8.2%) of their averaged audiograms. Group 2 do not have the frequency 2000 Hz affected in their audiogram and this minimal difference in audiogram configuration may play a vital role in predicting the degree of hearing handicap experienced in NIHL. The notable difference in the presenting problems for this group is that they complain of difficulties with speech in background noise, a complaint not mentioned by any of the other groups.

A comparison of Group 2 and Group 3 provides evidence of the impact that the frequency 2000 Hz being affected had on the degree of hearing handicap, as this frequency is the distinguishing factor between these two patterns. The difference of 13.1% in hearing handicap in these groups appears to indicate that minimal differences in audiogram configuration result in large differences in the degree of hearing handicap experienced. The comparison of these two groups also highlights the notable difference in PLH which may, therefore, be a valuable distinguishing factor for predicting the effect of NIHL on the quality of life of noise-exposed persons.

**Table 2. Summary of results**

Audio-gram Group	n	PLH	Degree and configuration of hearing loss	Description of hearing loss	Presenting difficulties	Situational Handicap (50 points)	Emotional handicap (50 points)	Total handicap	Degree of hearing handicap
1	27	4.1%	250 Hz–2 kHz: Normal 3–8 kHz: Mild	High frequency loss	Following conversations	23.5	29.2	47.7%	Significant
2	71	8.2%	250 Hz–2 kHz: Normal 3–8 kHz: Mod.Severe	High frequency (2 kHz not affected)	1. Speech in background noise 2. Following conversations	21.9	22.4	44.3%	Significant
3	65	24.3%	250 Hz –1 kHz: Normal 2 kHz: Moderate 3–8 kHz: Mod.Severe	High frequency (2 kHz affected)	Following conversations	28.2	29.2	57.4%	Significant
4	136	39.8%	250–500 Hz: Mild 1–2 kHz: Moderate 3–8 kHz: Mod. severe	All frequencies affected	1. Following conversations 2. General difficulty hearing	28.2	24.2	52.4%	Significant
5	40	69.6%	250 Hz –1 kHz: Mod.severe 2–4 kHz: Severe 6–8 kHz: Profound	All frequencies affected	Difficulty hearing in all situations	36.1	35.8	71.9%	Significant

Group 4, whose audiogram configuration depicts a mild to moderately severe hearing loss in all frequencies, interestingly indicates a slightly lower degree of hearing handicap (52.4%) than that reported by Group 3 (57.4%), whose audiogram configuration had normal hearing in the low frequencies.

Group 5, where the audiogram configuration showed a moderately severe to profound hearing loss across all frequencies, is distinct in that the PLH (69.6%) and degree of hearing loss are markedly greater than for the other groups and the presenting complaint is difficulty hearing in all situations. The experience of handicap is also markedly greater (71.9%) than for the other groups.

The questionnaire<sup>16</sup> (Table 1) distinguishes between situational handicap and emotional handicap. Situational handicap includes experiencing difficulties in group discussions, with the use of the telephone and in complex listening situations. Emotional handicap has an impact on the listener's self image and he experiences frustrations and limitations on his lifestyle as a result of his hearing loss.

Groups 4 and 5 (for whom all frequencies are affected on the audiograms) reported a greater situational handicap than emotional handicap, while the groups who have some frequencies on their audiograms within normal limits, appear to experience more emotional handicap than situational handicap. The reason for this difference is unclear, but it raises questions about the emotional effects of NIHL and the impact on the quality of life, which should be investigated further.

The implications of these results for occupational audiology practice are that the presenting complaint and the audiogram configuration in a noise-exposed person may provide clues as to the extent of hearing handicap experienced by the person. The fitting of hearing aids should be considered only as the starting point of the rehabilitation process for this population. Furthermore, the results emphasise the need for the audiologist in clinical practice to be aware of the impact of the specific features of the audiogram configuration on the quality of life of persons exposed to noise. As a consequence, greater attention may be paid to frequency responses of hearing aids and listening devices during rehabilitation.

A model to predict the expected hearing handicap experienced based on the PLH of the noise-exposed worker has been developed from Table 2, and is depicted in Table 3. However, the categories are wide and research is required to further test and refine the predictive accuracy of the model. In particular, studies with large probability samples and robust investigation of the degree of association between the variables using inferential statistical tests need to be conducted.

An important implication of this type of model is the possibility of re-examining the current attitudes towards compensation and opening the debate on the policy to increase the need for rehabilitation benefits for NIHL victims, as well as revisiting the weighting of the PLH calculation tables used for compensation purposes. PLH should include an awareness of the impact that the hearing loss has on the noise-exposed person's quality of life and their experience of handicap. The model also has potential for an improved risk management framework which takes into account not only compensation for hearing loss but also its impact on the quality of life of a noise-exposed worker. By predicting the effect of NIHL, it could be included as a motivating tool for counselling in a hearing conservation programme. It also indicates the need for comprehensive rehabilitation for NIHL victims, including counselling regarding emotional and social adjustment to hearing loss, career change guidance and conservation of residual hearing.

## CONCLUSION

All the gold mine workers, with any degree of NIHL, in the study experienced significant hearing handicap, even those with mild hearing loss. It is also clear that various audiogram configurations were present and not only the expected and traditionally accepted 4000 Hz notch. There appears to be some relationship between the

**Table 3. Proposed model to predict hearing handicap from PLH**

PLH categories	Degree of hearing handicap
<4%	None
4–10%	40–50%
10–40%	50–60%
>40%	>60%

subjective experience of hearing handicap and the configuration of the audiogram, which could confirm findings in the literature that the greater the degree of hearing loss the greater the experience of handicap,<sup>5,8,20,21</sup> but further research is needed. The findings also highlight the need to further investigate the full effect of NIHL on all areas of the auditory system and on the person as a whole.

It can also be concluded that rehabilitation of a person with NIHL should take into account the specific emotional impact of the hearing handicap, as well as the value of using questionnaires to supplement audiological information.

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