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 experience of hearing handicap by gold miners with different audiogram configurations of NIHL was measured using the translated Hearing Handicap Inventory. Audiograms and measures of hearing handicap were associated with the PLH calculated from the tables specified by the South African compensation legislation. Results indicate that NIHL audiograms can be categorised into five different patterns based on the configuration. All participants, no matter what the 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.

Key words: mineworkers, noise induced hearing loss, handicap, Percentage Loss of Hearing

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 [1,2,3] . 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.

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 sensorineural 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 [4,5]. The function of the OHC is frequency selectivity and the selection of important stimuli, which assists the listener to exclude background sounds.[6] 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 [7,8,9]. 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 [10,11,12] . 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 [13] . 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, increased effort to communicate[14,15,16] . Other problems that are commonly experienced in NIHL victims are recruitment and tinnitus [12,5,17,18] . 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 [19] .

NIHL in South African miners

The health and safety of South African miners is potentially compromised 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 continues to result in a lower experience of quality of life for many South African miners [20,21] . 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[23,24]. The financial compensation for NIHL, however, gives little attention to 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 [2;22] , and has been investigated with various measurement tools to supplement the information found on an audiogram [25,26,3] . The quantification of the experience of handicap has been shown to be facilitated by the Hearing Handicap Inventory for the Elderly (HHI-E)[27] and the alternative format, Hearing Handicap Inventory for the Elderly (HHI-E) [27] , 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 corresponding audiometric configuration or degree of hearing loss[28].The audiogram configuration or degree of hearing loss is not necessarily indicative of the experience of hearing handicap and therefore of reduction in quality of life. Association between the audiogram configuration (and the PLH) and the experience of handicap in a NIHL population offers occupational audiology practice the potential of a model to quantify such a relationship.

Purpose of the study

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

Methodology

Participants:

The records from a private audiological practice in the North West Province of South Africa were used for this study. The audiology 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 sensorineural 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 819 questionnaires were sent to consenting prospective participants, of which 339 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) [29] was translated into Afrikaans by the principal researcher, a mother-tongue Afrikaans speaker, as the private practice where the records were sourced is in a predominantly Afrikaans-speaking area 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 [29, 30,31] .

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 nor movie theatres, but 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?) [29] .

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

Insert 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[33,34,35,4] and no significant difference between ears nor between air and bone conduction thresholds are 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[29,36,9]. 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 it 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 [29].

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 following categories are specified as the interpretation of the scores by the authors [27]:

- 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. All audiograms could be allocated to one of the following five groups based on the configuration:

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

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

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

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

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

The hearing handicap scores were averaged for the different audiogram configurations groups. PLH was calculated for each audiogram configuration group using the averaged hearing thresholds at frequencies 0.5; 1; 2; 3; and 4KHz as detailed in the PLH calculation tables[23] .

Results *Insert Figure 1*

Figure 1 graphically depicts the averaged pure tone thresholds of the better ears of the noise-exposed participants in this study. The five groups that categorise the averaged audiogram configurations are seen on the audiogram and the average pure tone threshold levels are listed in the legend.

Insert Table 2

Table 2 summarises the relationships that exist between the configuration patterns of the audiogram (expressed as a PLH) and the extent to which a noise-exposed person experiences hearing handicap both from a situational and an emotional perspective. The questionnaire (as shown in Table 1) probed the type of handicap experienced for everyday life situations such as group discussions and use of the telephone. It also investigated the impact the hearing loss has on the person's self-image and the limitations on their lifestyle that result from the NIHL. 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. The hearing handicap as measured by the HHI is regarded as having significant impact on the respondent's quality of life when the score is higher than 42%. Some unexpected findings require closer inspection.

Discussion

Subjects 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 2000Hz) 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 two are also surprising, as they appear to experience slightly less hearing handicap than the mild hearing loss group (Group one), despite the higher PLH (8.2%) of their averaged audiograms. Group two do not have the frequency 2000Hz 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 two and Group three is evidence of the impact on the degree of hearing handicap by the frequency 2000Hz being affected on the audiogram, as this frequency is the distinguishing factor between these two patterns The difference of 13.1% in hearing handicap in these groups is a clear indication that minimal differences in audiogram configuration will result in significant differences in the degree of hearing handicap experienced. The comparison of these two groups also highlights the significant 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.

Group four, 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 three (57.4%) whose audiogram has normal hearing in the low frequencies.

Group five, 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[29] (Table 1) distinguishes between situational handicap and emotional handicap. Groups four and five (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 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 will provide clues as to the extent of hearing handicap experienced by the person. The fitting of hearing aids should be considered as the starting point of the rehabilitation process for this population. The use of the information found in the results of this study for counselling purposes will add to the service provided to this population, and the audiologist in clinical practice needs to have an awareness of the impact of the specific features of the configuration of the audiogram on the quality of life of persons exposed to noise. If the audiologist is aware of the abovementioned audiogram features greater attention will be paid to frequency responses of hearing aids and listening devices during rehabilitation.

The results of this study highlight the need for an extension to the traditional use of PLH, namely as a measure of when compensation for NIHL will be paid. 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 that emerges from the results could predict the effect of NIHL and be included in a hearing conservation programme as a motivating tool for counselling. The planning of a comprehensive hearing prevention strategy should be alerted by the results of this study to be aware of the need for comprehensive rehabilitation for NIHL victims which would include counselling regarding emotional and social adjustment to hearing loss, career change guidance and conservation of residual hearing.

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.

Insert Table 3

The model resulting from this study is depicted in Table 3. The categories shown in Table 3 are wide and would require further research to refine the accuracy of

prediction of the expected hearing handicap experienced by a noise-exposed worker. The potential 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.

Conclusion:

On the basis of the findings of this study it can be concluded that gold mine workers with any degree of NIHL experience significant hearing handicap, even those with mild hearing loss. It is also clear that various audiogram configurations are found in this population and not only the expected and traditionally accepted 4000 Hz notch. There is a significant relationship between the subjective experience of hearing handicap and the configuration of the audiogram, which confirms findings in the literature that the greater the degree of hearing loss the greater the experience of handicap [40,9]. 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. A complete rehabilitation programme for this population should include not only specific amplification but also the awareness of employers of the impact of NIHL on the emotional well being of the workforce.

Future research needs to investigate if age, culture, education level and occupation types are related to the configurations evidenced in this study, as well as the effects of these variables on the experience of hearing handicap.

References:

1. Salomon, G., Vesterager, V. & Jagd M. Age Related Hearing Difficulties 1: Hearing Impairment, Disability and Handicap - A controlled study*, Audiology.* 1988;27:164.

2. Schow, R. L., & Gatehouse, S. Fundamental Issues in Self-Assessment of Hearing*, Ear & Hearing.* 1990;11(5) Supplement.

3. Ringdahl, A., Eriksson-Mangold, M. & Andersson, G. Psychometric Evaluation of the Gothenburg Profile for Measurement of Experienced Hearing Disability and

Handicap: Applications with New Hearing Aid Candidates and Experienced Hearing Aid Users. *British Journal of Audiology.* 1998;32:375.

4. Kramer, M. B., & Armbruster, J. M. Forensic Audiology. University Park Press: Baltimore, Maryland, 1982.

5. Dobie, R. A., Medical-Legal Evaluation of Hearing Loss. 2nd Edition, Singular: Thomson Learning, Canada, 2001.

6. Henderson, D., Salvi, R. J., Boettcher, F. A. & Clock, A. E. Neurophysiologic Correlates of Sensory-neural Hearing Loss, in Katz J, , Handbook of Clinical Audiology. Williams & Wilkins: Baltimore, Maryland. 1994.

7. Workman-Davies, C. L., Noise and Hearing in the Mining Industry. Project Report, University of the Witwatersrand, Johannesburg.1991.

8. Pavlovic, C. V., Speech Spectrum Considerations and Speech Intelligibility Predictions in Hearing Aid Evaluations. *Journal of Speech and Hearing Disorders* 1989; 54:3.

9. Bess, F. H. & Humes, L. E. Audiology the Fundamentals *(*2nd Ed), Williams & Wilkins: Baltimore, 1995.

10. Lundborg, T., Risberg, A., Holmqvist, C., Lindstrom, B. & Svard, I. Rehabilitative Procedures in Sensorineural Hearing Loss, *Scandinavian Audiology*. 1982; 11:161.

11. Suter, A. H. Speech Recognition in Noise by Individuals with Mild Hearing Impairments, *Jnl. Acoust. Soc. Am.* 1985; 78(3): 887.

12. Sataloff, R. T. & Sataloff, J. Occupational Hearing Loss. Marcel Dekker Inc: New York. 1987.

13. Green, D. S. & Huerta, L. Tests of Retrocochlear Function, In Katz, J. Handbook of Clinical Audiology. Williams & Wilkins: Baltimore, Maryland. 1994,

14. Kramer, S. E., Kapteyn, T. S. & Festen, J. M. The Self-reported Handicapping Effect of Hearing Disabilities. *Audiology*. 1998; 37:302.

15. Melnick, W. Industrial Hearing Conservation, In Katz, J. Handbook of Clinical Audiology. Williams & Wilkins: Baltimore, Maryland. 1994,

16. Kryter, K. D. The Effects of Noise on Man. Academic Press Inc: Orlando,1985.

17. Moore, B. C. J., Glasberg, B. R. & Vickers, D. A. Simulation of the Effects of Loudness Recruitment on the Intelligibility of Speech in Noise. *British Journal of Audiology*. 1995; 29:131.

18. Axelsson, A. & Barrenas, M. Tinnitus in Noise Induced Hearing Loss. In Dancer, A.L., Henderson, D., Salvi, R. J. & Hamernik, R. P. Noise Induced Hearing Loss. Mosby Year Book: St Louis, 1992.

19. Nairn, W. A. Noise Induced Deafness. Papers and Discussions, Association of Mine Managers, 1984;189.

20. Franz, R. M., Janse van Rensburg, A., Marx, H. E., Murray-Smith, A. I. & Hodgson, T. E. Develop Means to Enhance the Effectiveness of Existing Hearing Conservation Programmes. CSIR, Pretoria. 1997.

21. Edwards, A. The Characteristics of Noise Induced Hearing Loss in Gold Miners. Unpublished Masters thesis. University of Pretoria, Pretoria, 2002.

22. Noble, W. Hearing, Hearing Impairment and the Audible World: A Theoretical Essay. *Audiology*.1983; 22:325.

23. Government Gazette 16 May 2001 circular instruction no.171. The Determination of Permanent Disablement Resulting from Hearing Loss Caused by Eexposure to Excessive Noise and Trauma. Compensation for Occupational injuries and diseases act no.130 of 1993.

24. Republic of South-Africa, Department of Minerals and Energy. Mine Health and Safety Act No 29 of 1996. Pretoria: Government Printer,1996.

25. Alpiner, J. G. (ed) Handbook of Adult Rehabilitative Audiology, 2nd Ed. Williams & Wilkins: Baltimore, London,1982.

26. Jerger, S. & Jerger, J. Auditory Disorders: A Manual for Clinical Evaluation. Little, Brown & Co (Inc): USA,1981.

27. Ventry, I. M. & Weinstein, B. E. The Hearing Handicap Inventory for the Elderly: A New Tool. *Ear & Hearing*.1982; (3)128.

28. Ward, W. D. The American Medical Association/American Academy of Otolaryngology Formula for Determination of Hearing Handicap. *Audiology.*1983; 22:313.

29. Newman, C. W., Weinstein, B. E., Jacobson, G. P. & Hug, G. A. The Hearing Handicap Inventory for Adults: Psychometric Adequacy and Audiometric Correlates. *Ear & Hearing*. 1990;11(6):430.

30. Lichtenstein, M. J., Bess, F. H. & Logan, S. A. Diagnostic Performance of the Hearing Handicap Inventory for the Elderly (Screening Version) against Differing Definitions of Hearing Loss. *Ear & Hearing*. 1988;9 (4): 208.

31. Graziano, A. M. & Raulin, M. L. Research Methods: a Process of Inquiry. (2nd ed) Harper Collins Publishers: New York, 1993.

32. Punch, J. L. & Weinstein, B. E. The Hearing Handicap Inventory: Introducing A Multimedia version. *The Hearing Journal*. 1996;49(10): 35.

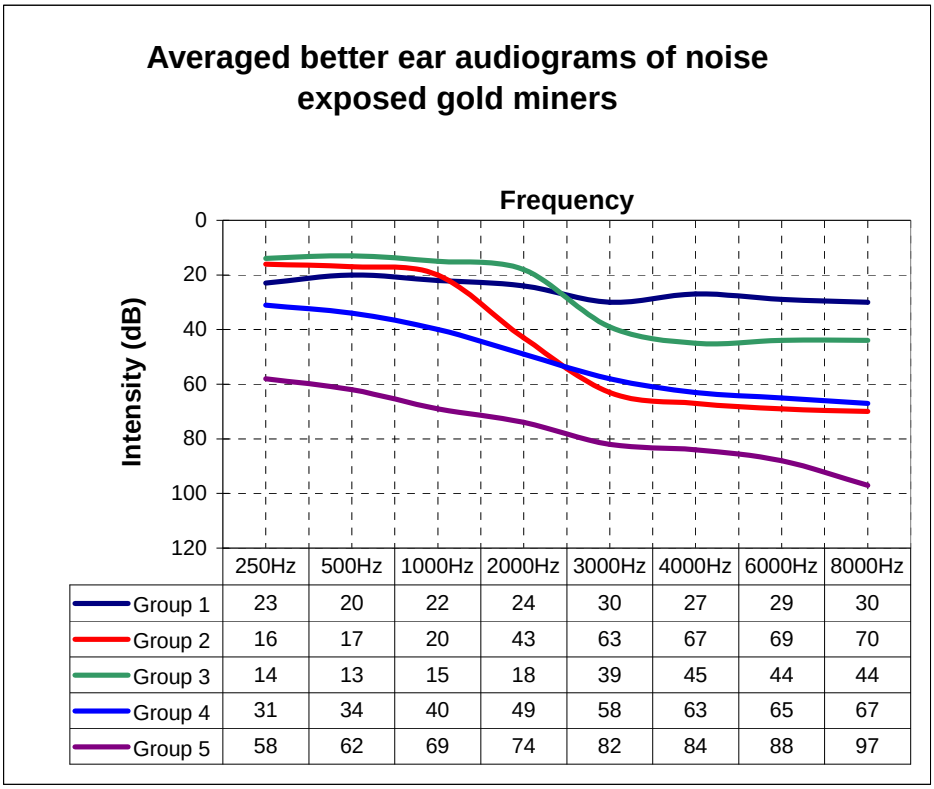
33. Roeser, R. J., Valente, M. & Hosford-Dunn, H. (eds). Audiology Diagnosis. New York: Thieme Medical Publishers, 2000.

34.Tyler, R. S. & Smith, P. A. Sentence Identification in Noise and Hearing-handicap Questionnaires. *Scandinavian Audiology*.1983; 12:285.

35. Phaneuf, R., Hetu, R. & James, J. A. A Bayesian Approach for predicting Judged Hearing Disability. *American Journal of Industrial Medicine*. 1985;7:343.
36. Hallberg, L. R-M., Barrenas, M-L. Coping with Noise-Induced Hearing Loss: Experiences from the Perspective of Middle-Aged Male Victims*. British Journal of Audiology* .1995;29: 219.
37. Hallberg, L. R-M. & Carlsson, S. G. Hearing Impairment, coping and perceived Hearing Loss in Middle-aged Subjects with Acquired Hearing Loss*. British Journal of Audiology*. 1991;25:323.

Table 1. Hearing Handicap Inventory for Adults (HHI-A)

Situational hearing Handicap	12 questions	Investigates hearing handicap in different everyday life situations	Examples : 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



	250Hz	500Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
Group 1	23	20	22	24	30	27	29	30
Group 2	16	17	20	43	63	67	69	70
Group 3	14	13	15	18	39	45	44	44
Group 4	31	34	40	49	58	63	65	67
Group 5	58	62	69	74	82	84	88	97

Figure 1. Averaged pure-tone threshold in decibels of noise exposed gold miners of better ear.

Table 2. Summary of results

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%	250-2kHz: Normal 3-8kHz: Mild	High frequency loss	Following conversations	23.5	29.2	47.7%	Significant
2	71	8.2%	250-2kHz: Normal 3-8kHz: Mod.Severe	High frequency (2kHz not affected)	1.Speech in background noise 2. Following conversations	21.9	22.4	44.3%	Significant
3	65	24.3%	250-1kHz: Normal 2kHz:Moderate 3-8kHz: Mod.Severe	High frequency (2kHz affected)	Following conversations	28.2	29.2	57.4%	Significant
4	136	39.8%	250-500Hz: mild 1-2kHz: moderate 3-8kHz: Mod.Severe	All frequencies affected	1.Following conversations 2. General difficulty hearing	28.2	24.2	52.4%	Significant
5	40	69.6%	250-1kHz:Mod.severe 2-4KHz:severe 6-8kHz:Pofound	All frequencies affected	Difficulty hearing in all situations	36.1	35.8	71.9%	Significant

Table 3. Hearing handicap and PLH

PLH	Hearing handicap
<4%	None
4-10%	40-50%
10-40%	50-60%
>40%	>60%