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Characteristics of noise-induced hearing loss in gold miners

by

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TITLE : ***Characteristics of Noise Induced Hearing Loss in Gold Miners***

ABSTRACT:

The characteristics of Noise Induced Hearing Loss (NIHL) in gold miners of different ages and occupation types were examined and the incidence of tinnitus, vertigo/balance problems and nausea were determined. The results indicate that as a subject group these had symmetrical bilateral, mild hearing loss in the frequencies below 2000 Hz deteriorating to a moderate sloping hearing loss in the frequencies above 2000 Hz, and the loss did not demonstrate the expected “notch” at 4000 Hz that is usually found in NIHL.

The average deterioration in the pure tone thresholds of gold miners was 3.5 dB at 500Hz; 2.75dB at 1000Hz, 15.37 dB at 2000Hz, 19.12 dB at 3000Hz; 20.87dB at 4000 Hz and 14.16dB at 6000 Hz for every ten years of age. The pattern of hearing loss varies for the different occupation types with machine operators being the most severely affected. The majority of tinnitus sufferers were in the age range 30-60 years and 57.8 % were in the under 60 years old category, while in the over 60 years the incidence was 4.8 %. The incidence of vertigo and nausea were found to be 27% in this population. The results of this study will equip the audiologist to better deal with diagnostic testing, successful hearing aid fitting and aural rehabilitation of this population. The study highlights the need for greater awareness and the imparting of detailed information to gold miners about the impact of noise on their hearing.

Key words: noise-induced hearing loss, gold miners, tinnitus, hearing conservation

OPSOMMING:

Die kenmerke van geraas-geïnduseerde gehoorverlies is bepaal vir ‘n groep goudmyners van verskillende ouderdomme en tydperke van diens. Variante wat ondersoek is, is gehoordrempels, voorkoms van tinnitus, vertigo /balans-steurnisse en voorkoms van naarheid. Die resultate toon dat hierdie populasie oor die algemeen ‘n bilaterale simmetriese gehoorverlies het, wat in die frekwensies onder 2000Hz gering is maar daarna verswak tot ‘n gemiddelde verlies in die frekwensies bo 2000Hz. Die oudiogram bevat nie die keep by 4000 Hz wat kenmerkend van geraas-geïnduseerde gehoorverlies is nie. Die gemiddelde jaarlikse afname in gehoorvermoë vir myners is .7dB by 4000 Hz en .75dB by 6000 Hz. Die patroon van die oudiogram het verskil vir die verskeie werksoorte, en masjien-operateurs se gehoor was die meeste aangetas. Die meerderheid tinnitus-lyers kom voor in die ouderdoms-groep 30-60 jaar. In die ouderdoms-groep onder 60 jaar het die meeste tinnitus-lyers voorgekom (57.8%), terwyl 4.8% in die bo 60-jaar groep voorkom. Vertigo/balans-probleme en naarheid kom by 27% van hierdie bevolking voor. Die resultate van die studie sal die oudioloog beter toerus vir diagnostiese toetsing, suksesvolle gehoorapparaat passing en aurale rehabilitasie by hierdie spesifieke populasie. Die studie beklemtoon die noodsaaklikheid van groter bewusmaking van, en inligtingverskaffing oor, die uitwerking van geraas op gehoorvermoë.

Sleutel terme: geraas-geïnduseerde gehoorverlies, goudmyners, tinnitus, gehoorbewaring.

INTRODUCTION

The high incidence of hazardous noise exposure is one of the many occupational risks experienced by gold miners. In the North West Province of South Africa the deep gold mining industry plays a vital role in the economy and life of many of the communities in the province. The result of the exposure to high levels of noise is the presence of NIHL in this population.

Noise Induced Hearing Loss

Authors and researchers (Melnick, 1994:534; Tempest, 1985:47; Mills, 1992:237) unanimously agree that exposure of the human ear to high intensities of noise, results in a sensori-neural hearing loss or what is known as Noise Induced Hearing Loss (NIHL). NIHL is characteristically a hearing loss where the damage incurred is chiefly to the cochlear hair cells. This damage may be the result of direct mechanical trauma to the delicate organ of Corti structures or the result of overdriving the metabolically dependent processes of the inner ear (Miller, Ren, Dengerik, Nuttal 1996:95).

The phenomenon of NIHL can be described as the irreversible shift in pure-tone thresholds from a specific base-line (American Standards, 1954:9), resulting from exposure to steady state or impulsive and impact noise at levels above 80 dB A (Tempest, 1985:48). This irreversible or permanent threshold shift is audiometrically characterised by an audiogram in which the higher frequencies between 3000 Hertz (Hz) and 6000 Hz are most severely affected, usually presenting with a 4000 Hz “dip” (Melnick, 1994:538; Celik, 1998:369; Tempest 1985:48). NIHL also often presents as an asymptotic loss in which severe loss develops in the high frequencies while the low frequencies evidence minimal loss, especially in specific job types such as jackhammer operators (Sataloff and Sataloff 1973:373).

However, individual susceptibility to NIHL within groups of people who have been similarly exposed to noise is a widely accepted phenomenon in NIHL research (Melnick, 1994:534; Tempest, 1985:61). A number of factors in the development of NIHL have been researched as possible contributing reasons for the individual susceptibility. The main factor appears to be that of age of the subject. Most of the research into the combined effects of age and noise exposure, has led to the conclusion that the effect of NIHL and Age Related Hearing Loss (ARHL) are additive in nature (Tempest, 1985:61; Dobie, 1992:19; Miller, Dolan, Raphael, Altschuler, 1998:53). Research in NIHL has resulted in the development of graphs indicating the expected hearing sensitivity levels for progressively older subjects in relation to the exposure periods (American Standards, 1954:4; Kryter, 1985:229; Dobie 1992:19; Henderson and Saunders, 1998: 120). Recent debate however, has suggested that the correction factor for the ARHL component of NIHL has more complex implications than simply subtraction from the hearing thresholds after noise exposure (Mills, 1992:238*)*. The “damaged ear “ theory, which suggests that the already damaged ear is at greater risk of further damage from continued noise exposure, than a normal ear, is at the heart of this debate. Recent research also points to lower metabolic rates related to aging as a factor that may increase the sensitivity of the ear to NIHL (Miller et al, 1998:53).

Other factors that influence the individual susceptibility to NIHL featuring in recent research include the effects of dynamic physical exercise (Dancer, Henderson, Salvi, Hamernik, 1992:501; Cristell, 1998:219), toxins (Dancer et al, 1992:184; Franks, 1996:447), drugs (Boettcher, Henderson, Gratton, Danielson, Bryne, 1987:192) and smoking (Virokannas, Anttonen, 1995:211). These aspects of NIHL and of possible influencing factors are all relevant to the worker in the deep gold mining industry and manifest in both auditory and non-auditory effects.

Non-Auditory Effects of Noise on Man

Thus far only the auditory effects of noise on the worker exposed to high levels of noise have been described, but the implications of exposure to noise extends to non-auditory effects. Non-auditory effects are dependent on the nature of the noise and are known to include symptoms related to the automatic nervous system, such as heightened skin temperatures, increased pulse rate, vascular pressure, nausea, fatigue, and decreased appetite (Sataloff &Sataloff 1973:44). Symptoms related to higher brain functioning have been documented including interference in thought processing and task execution. These symptoms result from greater concentration and listening effort needed when working in noise and can in turn lead to irritability, aggression, depression and disturbances in sleep patterns (Sataloff & Sataloff 1973:44). Another long-term non-auditory effect of NIHL has been shown to be the presence of tinnitus (Axelsson and Barrenas, 1992:269). Tinnitus can in many cases be debilitating for a patient and can influence sleep, moods, concentration, personality and in some cases speech recognition. Tinnitus occurs in approximately one third of cases with a history of noise exposure (Sataloff and Sataloff, 973:44; Axelsson and Barrenas, 1992: 269).

Legislation

Due to the fact that the symptoms and characteristics of NIHL discussed in the previous section are factors that negatively influence the lives of workers, the prevention measures have been legislated. The South African mining industry is governed by the Code of Practice for the Measurement and Assessment of Occupational Noise for Hearing Conservation purposes as laid down by the South African Bureau of Standards Document 083:1996 and as prescribed by the Mines and Works Act 1956.

The code of practice stipulates standards for measurement and rating of working environments for conservation purposes, and also the necessary hearing conservation measures to be applied. The legislation ensures that hearing conservation measures are implemented in the case of workers, for whom the noise-rating limit at 85dBA is exceeded. All employees who work in noise zones, as rated by the legislation in SABS 083:1996, are expected to undergo audiometric screening tests annually during the first three years of service and every two years thereafter. The referral threshold shift is defined as "any threshold at 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz or 8000 Hz, which deviates by more than 15dB if audiometric tests are conducted annually or 20dB if audiometric tests are conducted every two years" (SABS 083:1996:10). A referral threshold shift requires referral for diagnostic audiology to an audiologist who is registered with the South African Health Professions Council who will perform diagnostic audiology. If diagnostic audiological tests reveal that the permanent shift in the hearing thresholds was caused by exposure to noise, then a reportable incident as stated by the Occupational Health and Safety Act 1993 must be registered.

Audiology requires measurements of binaural hearing levels for at least 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz or 8000 Hz, so as to bring the audiologist to the conclusion that the permanent shift of hearing levels was caused by exposure to noise (SABS 083:1996:10). However, in many cases the validity of the hearing test results are in question due to malingering on the part of the patient. Further audiological testing is often carried out in practice to validate results, and in many cases simply to obtain results, as continued malingering hampers the diagnostic process. The malingering is due to the prospect of receiving financial compensation for permanent hearing disability. This financial compensation costs the industry a great deal and could be prevented through efficient Hearing Conservation Programmes.

Conservation of hearing

As mentioned above, an important aspect of NIHL is that it can be prevented (Melnick, 1994:534). The effort put into NIHL research demonstrates the concerted attempt to improve information, so that informed decisions can be made about ways to prevent NIHL. Due to the fact that noise and hearing are measurable factors Damage Risk Criteria have been drawn up by scientists and professionals in the field of NIHL. These criteria specify the noise exposure limits for workers, in an attempt to reduce the risk of hearing loss (Melnick, 1994:534; Tempest, 1985:62; SABS 083:1996). Developments in technology, both in the fields of measurement of hearing and in the most effective reduction of noise, open new possibilities for improved conservation. They provide procedures whereby specific details of the worker's hearing loss can be monitored to give early indications of subtle alterations to the hearing functions (Sallustio, Portalatini, Soleo, Cassano, Pesoloa, Lasorsa & Quaranta, 1998:95). Recent research has suggested possibilities of further preventing NIHL by pharmacological means (Abdulla, 1998:284) and by means of sound conditioning or prior exposure to low-level noise (Canlon, Dalgi, 1996:172).

The process of prevention of hearing losses is legislated and requires that hearing conservation programmes must be reviewed regularly to ensure their effectiveness. In areas where the noise level limit equals or exceeds 85dBA, reduction of noise levels is the first step in attempting to conserve the hearing of workers. The engineering of noise reduction may take the form of acoustically insulating either the source of the noise or the operator. In areas where the noise rating level cannot be reduced to below 85dBA the area must be clearly demarcated using the mandatory signs to indicate a noise area. All employees entering the noise zone are then obliged to wear hearing protectors that comply with regulations (SABS 083:1996:10).

Wearing of hearing protection needs to be monitored and employees who work in noise zones must undergo the specified audiometric testing on an annual or biannual basis, due to the fact that hearing protectors do not provide adequate protection under all circumstances (SABS 083:1996:10). Individual susceptibility to noise is a further important factor to be considered in NIHL.

Compensation for NIHL

When conservation has not been well planned and implemented the medico-legal implications have economic consequences in the form of compensation paid to workers for permanent hearing disability. Once the diagnostic audiology tests referred to in the previous section have been conducted, the percentage of permanent disability is calculated according to a formula accepted by the Workmen's Compensation Officer (Tempest 1985:55; SABS 083:1996:12). In accordance with general worldwide practice the formulae for calculations were changed in 1995 to include the 3000Hz frequency in the averaging of 500Hz, 1000Hz, and 2000Hz. The audiometric configuration of a typical NIHL, namely an asymptotic pattern, disadvantages the percentage of permanent disability and controversy exists about the frequencies to be included in the formula (Delaney, 1994). Some medico-legal situations require allocation of liability for compensation between a noise component and an age related component and models for this purpose have been proposed and tested (Dobie, 1992: 415; Mills, Fu-Shing, Dubno, and Boettcher in Axellsson et al., 1996: 193). In some countries workers are also compensated for tinnitus. However, due to the subjective nature of the symptom and the difficulties with the reasons for compensation, e.g. for decreased speech perception or for general annoyance associated with tinnitus, many difficulties arise. These difficulties necessitate a detailed procedure that includes careful history taking, tinnitus analysis and diagnostic audiometry as well as family questionnaire responses. In South Africa tinnitus and its effects are not compensated for.

The implication of these issues for the audiologist, is the need for accurate and practical skills to save the industry money, to ensure that the hearing impaired are adequately and fairly compensated, and to ensure successful rehabilitation through hearing aid fitting and hearing rehabilitation programmes. This also true for audiologists working in a gold mining environment, who need specific information relating to the gold mining industry

Gold Mining Industry

A more specific discussion about the gold mining industry is indicated at this point. The theoretical concepts and existing knowledge about NIHL have been well documented for a number of different industry types. These include cotton and jute weavers (Robinson, 1970:146); forest workers (Robinson, 1970:35-42); hydroelectric power plant workers (Celik, 1997:369); coal miners (Spies, 1995:34); platinum miners (Nairn, 1984:194); automobile metal pressing plant workers (Bruhl, Ivarsson, Tormalm 1994:83) and railway workers (Henderson & Saunders, 1998:120). The gold mining industry has specific attributes that could impact on the characteristics of the NIHL found in gold miners. These include the fact that the working environment can be up to two kilometers underground and up to ten kilometers into the mine on a vertical plane. Here, miners work on the rock face for many hours a day, often exceeding the usual 8 hour working day, in the presence of high levels of noise from machinery such as drilling equipment, ventilation equipment and transportation equipment, in confined areas which may also impact on the acoustical effects that the noise has on the workers (Franz, Janse van Rensburg, Marx, Murray-Smith and Hodgson, 1997:47).

Noise exposure levels associated with various job types in the South African gold mining environment have been documented as far exceeding the legislated level of 85dBA (Kielblock, Van Rensburg, Franz & Marx, 1991:129). The research organization of the Chamber of Mines has reported (Schroeder, van Rensburg, Schutte & Strydom, 1980:8) that underground and surface mining equipment such as jackhammers, pneumatic drills, ball mills, air compressors, drilling equipment, stoping and developing equipment and equipment for bending, riveting, grinding and cutting steel plate, are known to emit noise levels of up to 120 dBA. Recent research in South Africa has resulted in updated and comprehensive knowledge about the intensities and spectrum of the noise to which miners in South Africa are exposed, and comprehensive information for conservation programmes is now available (Franz et al.1997: 118). This extensive research into the emission levels and spectrum of noise in mining environments showed that “all production personnel are at considerable risk with regard to noise exposure” and “noise emission levels and particularly worker exposure levels in conventional gold and platinum mining appear to have increased” (Franz et al 1997:131), due to the need for increased productivity. These circumstances will of course impact on the hearing of workers.

Kielblock et al. (1991:129) have noted that although their research results were based on constraints applying to platinum miners, gold miners were expected to have similar results. They found that only 2-3% of platinum miners exhibited binaural hearing impairment (BHI) higher than 25 %, while 10% of drill operators or their assistants fell into this category. As mentioned earlier, high temperatures, physical exercise and toxins may all influence the escalation of NIHL and these are also factors present in the deep gold mining environment. The preceding discussion implies that the deep gold mining environment will result in specific characteristics in the NIHL.

Rationale

The existing body of knowledge on NIHL is extensive. However, the preceding discussion evokes the question: Does the NIHL found in deep gold mine workers have unique characteristics? The rationale for the study is the audiologist's need to have detailed information about NIHL in the deep gold mining industry (and therefore the answer to the above question), for the purpose of attainting best clinical practice with this population, for example awareness of expected hearing loss. Hearing conservation programmes need to be regularly reviewed, therefore the deep gold mining industry needs audiological information that will help to make decisions concerning it's hearing conservation programmes, for example the information that needs to be conveyed to gold miners about the dangers to their hearing.

METHODOLOGY

Research Aim

To determine the characteristics of NIHL in gold miners.

Sub-aims of study

-To determine the mean pure tone thresholds of gold miners

-To determine the influence of years of service on the pure tone thresholds of gold miners, by comparing audiograms from progressively longer periods of years of service in a deep gold mining environment.

-To determine the influence of age on the pure tone thresholds of gold miners, by comparing audiograms from progressively older subjects.

-To identify specific audiogram characteristics for different occupation types of deep gold mine workers.

-To determine the incidence of reported tinnitus in gold miners.

-To determine the incidence of reported vertigo/balance and nausea problems in deep gold mine workers.

Research design

The operational framework for this study was historical in nature resulting from the organization of evidence derived from audiometric records. The research comprised of a combination of what Leedy (1980:98) described as an analytical survey and what he described as a descriptive survey. The research methodology was analytical due to the quantitative nature of some of the data, and therefore inferential statistics were used to analyze the data. It was also descriptive, due to the ordinal nature of some of the data e.g. the measurement of the degree of the hearing loss, which was measured on an interval scale. The analysis had the purpose of finding central tendencies, variation and degree of interrelationship between variables in the data and was therefore also a descriptive analysis.

Data for this study was taken from the audiometric records at an audiology practice where deep gold mineworkers are referred to for diagnostic audiology once their hearing deteriorates below the referral threshold. The records consisted of a case history report for each subject and pure-tone air and bone conduction audiograms for right and left ears respectively.

Subjects

Gold mining is found in South Africa across a wide geographical area. The researcher works in a private audiology practice in the North West Province of South Africa in the town of Klerksdorp, which is a typical gold mining area in South Africa. Although the study is limited to this geographical area further research may indicate that the sample was typical and representative of gold miners in the mining industry. The subjects had all been exposed to noise in a deep gold mine environment where, as previously discussed, the noise levels exceed 85dbA. The ages of these subjects typified the ages of workers in deep gold mines. The data was representative of deep gold mine worker for both surface and underground job types. The audiograms found in this data therefore would give an accurate indication of what characteristics are found in NIHL in gold miners.

Due to the fact that large numbers of subjects were necessary to establish statistical trends in the characteristics of NIHL in gold miners the chosen research design was to document the records at an audiology practice that had been testing gold miners since 1992. All the records in the practice were used therefore including all records from the start of the practice. Audiograms and case history information from the data gave a measurable indication of the effects of exposure to the typical levels of noise in a deep gold mining environment. Also included was information on the reported non-auditory effects of balance, vertigo and nausea problems as well as the presence of tinnitus. From a total of 3464 gold miners tested at an audiology practice between January 1992 and December 1999, 866 were systematically sampled with a random starting point. This sampling method ensured that each record had an equal chance of being selected and resulted in 25% of the population being selected for analysis of the data. This was considered representative of the population and an appropriate sample size for time and convenience constraints.

Two audiograms for each subject were available, namely a right and a left pure-tone air conduction audiogram. Therefore 1732 audiograms were used for analysis.

Criteria for selection of subjects:

- Subjects had to have been exposed to noise levels in excess of 85dBA in their occupation type in a deep gold mine. This was to ensure exclusion of records of subjects who had been referred for testing, but who did not work in the mine e.g. laundry and hospital.
- Subjects had to have a complete history and audiometric record. A complete history was defined as one which included at least year of birth and year of testing, the number of years of service in a deep gold mine, the occupation type at the time of testing, and a record of the result of the air conduction and bone conduction audiometry at 250 Hz, 500 Hz, 1000 Hz, 2000Hz, 3000Hz, 4000 Hz, 6000 Hz and 8000 Hz, for at least one ear. This ensured the exclusion of those records where only screening had been done on days when the mine was having difficulties with their audiometric screening equipment and were referring employees only for screening.
- Subjects had to have a sensori-neural hearing loss i.e. no greater than 10 dB difference between the mean of 500 Hz, 1000 Hz and 2000 Hz for air conduction results and bone conduction results. The motivation for this criterion was to ensure that the definition of NIHL was adhered to and to exclude the many conductive losses found in this population.

Subject sampling and characteristics

The subjects were chosen due to their exposure to noise in deep gold mining working environments. The reported period of working in the deep gold mine by the subject was noted as the period of exposure to noise in the deep gold mining industry. The ages of the subjects ranged from 25 years to 65 years (Table 1) and subjects were divided into four groups for the purpose of analyzing the data, viz. 25 to 35 years, 35 to 45 years, 45 to 55 years, and 55 to 65 years. The number of subjects in the four age groups totaled 780, with 1560 audiograms. The years of service of the subjects were divided into categories of 10-year periods for easier analysis (Table 2). The number of subjects analyzed totaled 784 resulting in 1568 audiograms. The slight differences in numbers are due to missing values for certain variables in some of the subjects.

All age categories were included to obtain information about all possible periods of exposure to noise. The occupation type as reported at the interview was assumed to be the predominant occupation type followed by the subject during his working career. Unfortunately, no specific records were available to indicate whether subjects had changed occupation during the duration of the working history on the deep gold mine. For statistical purposes, only occupation categories that contained a sufficient number of subjects to give reliable results i.e. more than 30 subjects were used in the analysis (Table 3). This resulted in the following nine occupation categories being analyzed: boilermakers, drillers, winch operators, loco drivers, shiftbosses, miners, stopers, machine operators and team leaders.

When analyzing the incidence of tinnitus, vertigo/balance problems and nausea problems the subjects who had complete records varied and as a result the numbers of subjects used for analysis varied as represented in table 4.

The numbers vary from analysis to analysis due to incomplete records for some subjects a factor that was realized only once the sampling and recording process had begun. Further research may be simplified by only using records for which all data were available.

Table 1. Age distribution of subjects

Age	Subjects
<29 years	35
30-39 years	168
40-49 years	269
50-59 years	253
>60 years	55
Total	780
Total audiograms	1560

Table 2. Years of service distribution of subjects

Years of Service	Subjects
1-10 years	111
11-20 years	230
21-30 years	252
31-40 years	174
41-50 years	17
Total	784
Total audiograms	1568

Table 3. Number of subjects analyzed for years of service in relation to occupation type

Occupation	Years of Service				
	1-10	11-20	21-30	31-40	41-50	Total
Boilermaker	6	13	17	11	2	49
Driller	10	22	19	14	3	68
Winch operator	3	11	8	10	1	33
Loco driver	8	9	10	8	1	36
Shiftboss	3	17	17	13	0	50
Miner	17	20	21	15	1	74
Stoper	11	13	10	2	0	36
Machine operator	15	37	56	29	2	139
Team Leader	4	7	11	14	1	37
Total	77	149	169	116	11	522

Table 4. Number of subjects analyzed for tinnitus and vertigo/balance and nausea.

Variable	Tinnitus	Vertigo/Balance/Nausea
Total	**775**	**742**

MATERIALS AND APPARATUS

Materials and Apparatus used for gathering of data

The two partners of the audiology practice gathered the data, and they used the following materials and apparatus for gathering the data:

Audiometers

The GSI 16 diagnostic audiometer (Serial No. 5906) was used to gather the data for this study. The earphones used with this audiometer were Telephonics model TDH-50P (Serial no. C15287/8). The Bone vibrator was a Radio Ear model B71 (Serial no. 5906). These all complied with the requirements for equipment as stipulated by SABS 083:1996:14 and had been calibrated annually in accordance with the requirements for the measurement equipment for diagnostic testing.

Test Booths

The tests were conducted in a self-constructed audiometric booth, which complied with the regulations of SABS 083:1996:14 situated at the private practice of Michaelides and Vermaas in Klerksdorp. The audiometric booth was calibrated annually by a certified technician and was deemed suitable for Diagnostic Audiometric testing as stipulated in SABS 083:1996:14

Case History and Audiograms

Responses of each subject during the diagnostic audiology interview were recorded on the one side of a record sheet (See Appendix). This included the name; company identity number; date of birth; date of test; the reported occupation type at the time of testing and number of years of service in a deep gold mine for each mineworker. Further information included the diagnosis of the hearing loss by an Ear, Nose and

Throat Specialist as being NIHL; the patient's description of the problem, and the reported onset and development of the hearing loss. The record for each subject also included a reported history of middle ear problems and of balance, vertigo or nausea problems, the reported presence of tinnitus and whether the subject had had a test or a hearing aid before. The other side of the record form recorded the right and left audiogram, Pure Tone Average (PTA), Speech Reception Thresholds (SRT) and Speech Discrimination test results when these had been obtained.
These results were not used in the study due to the lack of standardization during testing, for example different testers voices used and conversational vernacular was used for the non- English speakers.

Materials and Apparatus for the recording of the data

Files

Sixty-two files containing the records of subjects were used to obtain the data for analysis in this study. All record forms were filed numerically according to the company number in files.

Computer

A desktop 366KHz personal computer with Windows 2000 Premium installed and using a Microsoft Office 2000 software package was used to record data onto the Excel program.

Materials and Apparatus for the analysis of the data

Computer program

The data was analyzed using the SAS package Version 8.2 (2001).

PROCEDURE

The material and equipment were used in the following procedures in the study.

Procedure for Collecting of data

At the time of making the appointment, subjects were asked to remove themselves from the work environment for a period of at least 16 hours before the tests were performed to ensure recovery from temporary threshold shift and in compliance with legislation (Melnick 1994: 537; SABS 083:1996:13).

Case History

The standard audiological practice of history taking from the subjects and of testing were performed by the two partners of this practice who are qualified Audiologists registered with the South African Health Professions Council as required by the legislation (SABS 083:1996:14). The case history was recorded during a personal interview with the subject using a translator when necessary.

Audiometry

The pure-tone thresholds (air and bone conduction) for frequencies 250Hz, 500HZ, 1000Hz, 200Hz, 3000Hz, 4000Hz, 6000Hz and air conduction only at 8000Hz were measured for both left and right ears using the descending method (Katz 1994:101). Narrow-band noise masking was used for contra-lateral masking in the pure-tone audiometry when necessary in accordance with standard audiological procedures (Katz 1994:119). The threshold results were plotted onto an audiogram by hand (see Appendix). The PTA was calculated by calculating the mean of 500 Hz, 1000 Hz and 2000 Hz. The SRT was then established using spondaic words and the descending method (Katz 1994:150). Speech Discrimination results were established using the CID-W22 phonetically balanced word lists or conversational speech in the live voices of the two audiologists (Katz 1994:152). This was carried out in the patients' home language or in Fanagalo when the audiologist was unable to speak the patient's home language. The audiograms were interpreted according to the degree of loss (ranging from mild to profound) and the type of loss (conductive, sensori-neural or mixed).

Interpretation of audiograms and case history information

The procedures resulted in a record for each subject that was filed in a filing system. Some of the records in the files used to gather the data for this study did not contain all the required information. This was due to the fact that at times screening audiometry, which did not require complete subject information, was carried out at the audiology practice, and these records were included in the files mentioned. These records were interspersed in the files used due to the filing system used in the practice. Removing these incomplete files would corrupt the random sampling process, thus they were included in the numbering system used for the sampling of data.

Records were interpreted to be adequate for inclusion in the study, when the information included at least, a birth date and a test date, the number of years of service in a deep gold mine, and an audiogram with a pure tone air and bone conduction threshold for 250Hz, 500Hz, 1000Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz, and 8000Hz in at least one ear.

Procedure for Capturing of data

The data was collected over a period of 7 years during the daily routine testing of the audiology practice and kept in the record system. The researcher then decided to use this information to gain better insight into NIHL in gold miners.

Coding data

The researcher organized the data by coding each subject record according to a numbering system that included both the file number and the record number. A random starting point was calculated and every fourth record was then captured onto the Office 2000 Excel spread sheet. The captured data was then e-mailed to the Statistics department at the University of Pretoria. The data was analyzed with the help of a Statistician of this department and a Senior Research Consultant, using the SAS package Version 8.2 (2001).

Procedure for Analysis of Data

Mean Hearing Loss

Data was analyzed for the mean threshold value for the frequencies 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz of the right ear and left ear respectively, for each subject. For purposes of convenience, the means were rounded down to the nearest whole number for all the analyses in this study before being used to create graphs and tables.

Age and Years of Service

Mean threshold values and standard deviation for each of the abovementioned frequencies were found for the different categories of years of service and of age. The number of audiograms used for analysis varied slightly due to slight variations in the information available on the audiometric records but all analyses consisted of more than 1400 audiograms.

Occupation type

Only occupation types that had sample sizes greater than 30 observations were used for analysis. To give an indication of the influence of occupation type on the hearing loss, the means of the abovementioned frequencies were calculated for occupation types, despite the lack of information on how long the worker had been in the job type, and if he had changed occupation types during his working career.

Incidence of tinnitus

The incidence of reported tinnitus and its relation to age, years of service, occupation types and degree of hearing loss and surface or underground occupation type were analyzed by calculating the means and by cross tabulations using Chi-squared tests.

Incidence of vertigo/balance problems

Determining the frequencies on each variable and then combining the results of the two categories calculated the incidence of reported vertigo and balance problems. This was done because it was considered that these two categories were very closely related to one another and it may have been difficult for subjects to distinguish between the two concepts during the interview.

Incidence of nausea

The incidence of reported nausea problems was tabulated in a frequency table.

Analysis of Variance

The analysis of variance was done using the SAS package Version 8.2 (2001). A General Linear Model analysis of variance was carried out for age, years of service and occupation type to determine which age categories, years of service categories and which occupational types have an influence on the audiogram for the experimental frequencies. Post hoc Duncan's tests, again using the SAS package, were done for pair-wise comparisons of significant differences in the relevant frequencies for each of the mentioned variables.

RESULTS

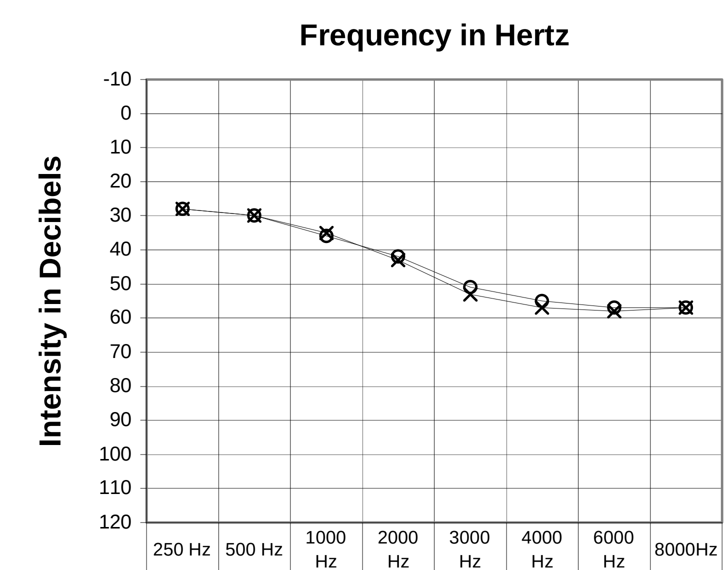
Results are discussed according to the aims set out in the methodology of this study.

Main aim: To determine the characteristics of NIHL in gold miners

The main aim of this study was to determine the characteristics of NIHL in gold miners, i.e. the unique attributes of the audiogram that one can expect to find when a subject has worked in deep gold mining noise.

Sub-aims 1: To determine the mean pure tone thresholds of gold miners

Figure 1 indicates the mean pure tone thresholds for the sampled population for right and left ears respectively.



	250 Hz	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz	8000Hz
Right Ear	28	30	36	42	51	55	57	57
Left Ear	28	30	35	43	53	57	58	57

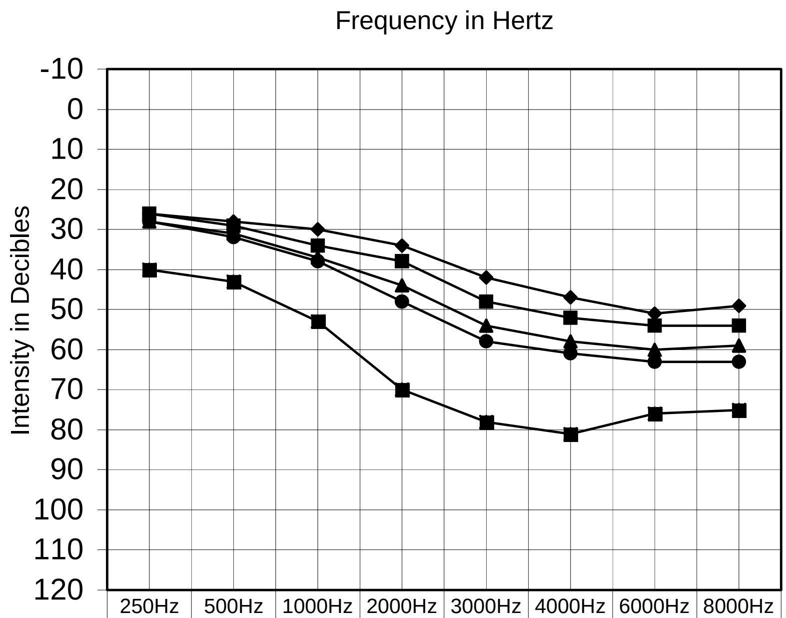
Figure 1. Mean Pure Tone Thresholds of Gold Miners

The audiogram indicates a bilateral, mild hearing loss in the frequencies below 2000 Hz deteriorating to a moderate sloping hearing loss in the frequencies above 2000 Hz. The means for the two ears indicate a symmetric loss and do not demonstrate the expected “notch” at 4000 Hz that is usually found in NIHL. It is evident that this population’s hearing had already deteriorated below the referral threshold of 25dB as the thresholds for all frequencies were below 25dB on the audiogram. This may also be one of the limitations of this study, namely that these subjects were more susceptible to NIHL because they had developed a hearing loss and were referred for further testing. These results indicate that the frequencies above 2000 Hz are largely equally affected as seen in the results for the frequencies 3000 Hz, 4000 Hz, 6000 Hz and 8000 Hz. Thresholds for all of these frequencies are between 50dB and 60 dB. These results differ from Hessel et al. who found an "exaggerated loss in the 4000-6000 Hz range (typical of noise-induced hearing loss) and a greater loss observed for the left ear than the right ear" (1987:365) in their population of white gold miners. A more severely affected left ear was not found in this population. This may be due to the fact that during the period when Hessel et al.'s study was conducted, "job reservation" was a factor in the gold mining industry. This may have resulted in white gold miners being exposed to particular noise types and levels due to their particular job type, which may have affected the results. This study includes a more representative sample of the deep gold mining population.

The absence of the typical NIHL "notch" in these results may be a reflection of the unique and specific type of noise and the intensities found in a deep gold mine (Franz et al.1997: 118), which result in a hearing loss where the high frequency areas (above 4000Hz) of the cochlea are damaged. These possibilities require further investigation into the interrelatedness between noise type and the resultant hearing loss. Due to the fact that "NIHL is the largest single compensatible illness in the world" (Abdulla 1998:284), the important implication of these results for the gold miner however, is the importance of education about the impact on unprotected ears in the deep gold mining environment and the effects on the miner's communication abilities as a result of the NIHL. "Education, increased use of physical ear protectors, and strictly policed environmental noise standards can go a long way to reducing the incidence of NIHL" (Abdulla 1998:284).

Sub-aim 2: To determine the influence of years of service on the characteristics of the NIHL

The second of the sub-aims was to establish whether the number of years of service in a deep gold mine had an influence on the NIHL and if so, in what way. Figure 2 represents the relationship of pure tone thresholds to years of service in this population.



	250Hz	500Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
1-10 years	26	28	30	34	42	47	51	49
11-20 years	26	29	34	38	48	52	54	54
21-30 years	28	31	37	44	54	58	60	59
31-40 years	28	32	38	48	58	61	63	63
41-50 years	40	43	53	70	78	81	76	75

Figure 2. Mean Binaural Pure Tone Thresholds for Years of Service

The results of the mean binaural pure tone thresholds for gold miners in relation to the years of service in Figure 2, indicates the deterioration of the pure tone thresholds as years of service in a deep gold mine increases. Within the first ten years the hearing is affected in the low frequencies to a mild degree and in the high frequencies moderately. Each following period of ten years of service, results in a deterioration of approximately 4-6dB per ten years for all frequencies. However, after 40 years of service the rate of growth increases by 15-20dB. The only category where there is some evidence of the “notch” that is characteristic of NIHL is at 41-50 years of service. The recovery of the threshold occurs at both 6000Hz and 8000Hz, but only by 5dB, which does not result in a typical notch. All other years of service categories have very similar thresholds for frequencies 3000-8000 Hz, resulting in a slightly sloping to flat threshold pattern.

The value of the results of this sub-aim is that it gives a good indication of what can be expected after a certain number of years of service. This could be useful in the clinical situation where the audiologist must establish reliable thresholds. Inexperienced audiologists working in a new field of gold mining may in particular find this helpful. The results of this sub-aim would also be important when presenting counseling and instruction programmes to convey to miners the effects of unprotected ears in a deep gold mining environment. Figure 3 is a representation of the mean pure tone average compared to the gold miner's years of service.

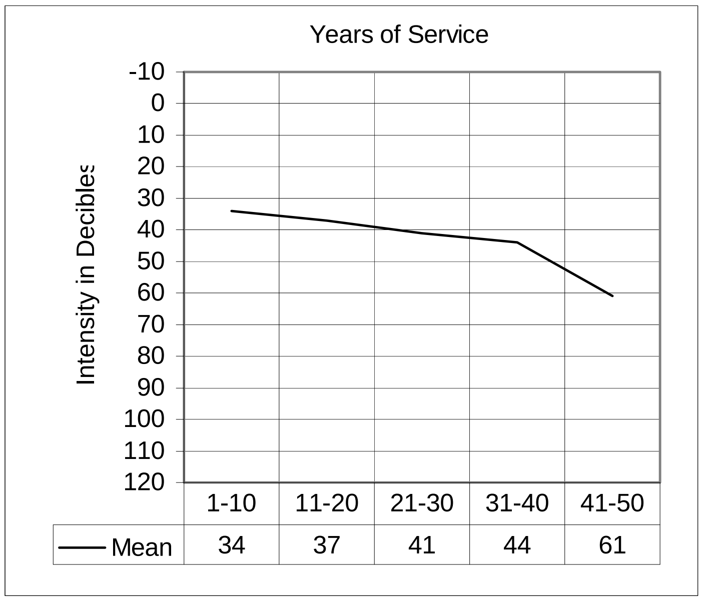


Figure 3. Mean Pure Tone Thresholds of 500Hz, 1000Hz and 2000Hz compared to Years of Service.

The results in figure 3 show the expected rate of growth of NIHL in a deep gold mine. The hearing loss will on average deteriorate to a mean of 34 dB after ten years of service. The deterioration between 11 and 40 years of service varies from 3 dB to 4dB per ten years of service. However, for the category of 41-50 years of service the deterioration dramatically increases by 17 dB. Therefore, a deep gold mine worker can expect to have a sloping moderate to severe hearing loss after 40 years or more of service. The calculations for this graph used the three frequencies 500, 1000 and 2000 Hz to compare the progression of NIHL in gold miners to that in railway workers. Henderson and Saunders (1998:121) stated: "Virtually all surveys of NIHL report that hearing loss (mean at 0.5, 1, 2, and 3 KHz) grows most rapidly during the first few years of noise exposure and the rate of growth slows with ensuing years.” This study confirms the first part of this statement but finds that after 40 years of service in a deep gold mine there is once again a rapid rate of growth. Henderson and Saunders (1998) compared the NIHL in a similar group of subjects from the railway industry to the International Standards Organizations’ model, the ISO: 1999 of expected NIHL. They found that the model could predict NIHL in railway workers. The fact that these results differ from Henderson and Saunders’ statement about the rate of growth of NIHL, warrants further investigation by comparing gold miner’s NIHL to the ISO: 1999 model. If this proves to be different, as would be expected, the implication would be that NIHL in gold miners does not compare to any other development of NIHL. This finding would have implications of needing to take extra care in the deep gold mining industry in the hearing conservation programmes. It may also result in greater awareness in the industry of the costs involved in compensation compared to other industries. The clinical implications for the audiologist are more specific expected results in this population, which would be a further tool to prevent malingering as well as greater awareness of hearing aid needs and aural rehabilitation needs. Planning also becomes a further possibility for the Human Resources management team of the deep gold mining industry, as they can more reliably predict the impact of the noise on their miners and therefore the costs involved, as well as the impact on the miner’s communicative abilities. The summary of the Duncan’s Test results in table 5 indicates that the hearing ability is significantly affected by the number of years of service in a deep gold mine at the frequencies 1000Hz, 2000Hz, 3000Hz and 4000Hz.

Table 5. Summary of the Duncan’s test results for frequencies in which the years of service make a significant difference

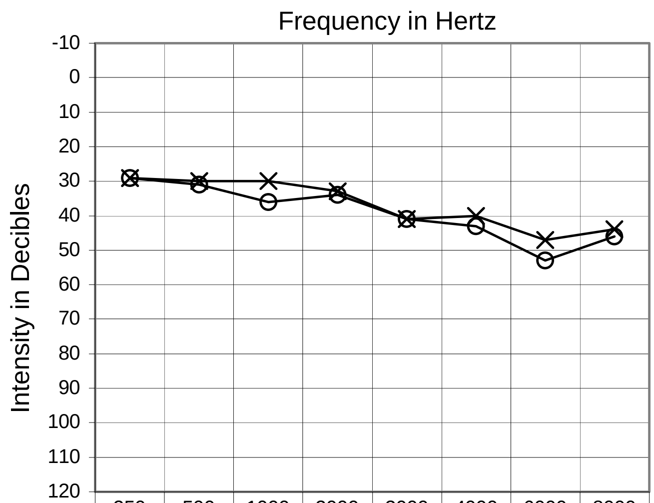
Frequency	1000 Hz	2000Hz	3000Hz	4000Hz
Years of service	41-50	41-50	41-50	41-50
	31-40	31-40	31-40	31-40
	1-10	1-10	1-10	21-30
				1-10

These significant differences also only occur in the years of service categories as indicated in table 5. This means that the frequency of 1000 Hz is significantly changed on the audiograms of the gold miners during the years between 1-10, and then not again until the gold miner has worked for at least 30 years. The hearing at the frequency of 1000 Hz is then affected significantly again during the period of service from 31- 50 years. It is also significant to note that 4000 Hz is affected in every age category except 11-20 years.

These results can be interpreted to show that the periods of most danger to the gold miner's hearing is during the first ten years, and after 30 years of service. The period after 30 years of service would also be affected by the influence of age on the hearing. However, one would then expect the frequencies above 4000 Hz also to be effected, as is the case in ARHL. The implication of this information is the necessity for effective communication to the workers of these dangers so that they will take the necessary responsibility to protect themselves against NIHL.

Sub-aim 3: To determine the influence of age on the NIHL of gold miners

The second sub-aim of this study was to establish whether the age of the subject had an influence on the NIHL and if so to what extent. The age categories are recorded on separate graphs for easier interpretation. Figures 4.1- 4.5 present the respective right and left ear mean pure tone threshold for the different age categories. The results in Figure 4.1 give an indication of the extent to which a gold miner's hearing can deteriorate, even before the age of 30 years.

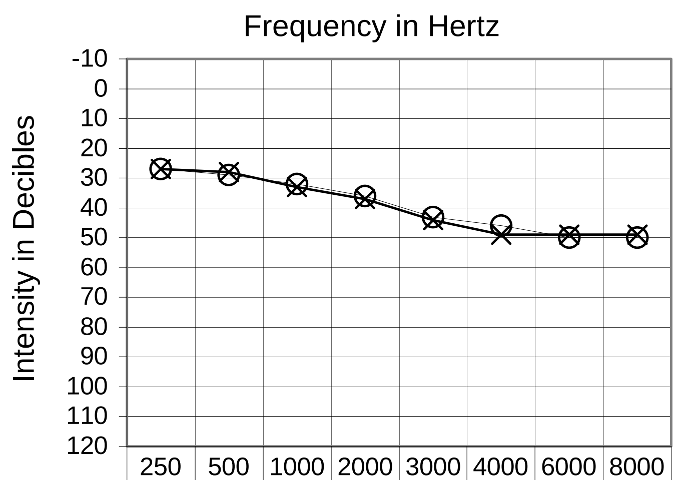


	250	500	1000	2000	3000	4000	6000	8000
Right Ear	29	31	36	34	41	43	53	46
Left Ear	29	30	30	33	41	40	47	44

Figure 4.1. Mean Pure Tone Thresholds for Ages <29 years of gold miners

The results in Figure 4.1 give an indication of the extent to which a gold miner's hearing can deteriorate, even before the age of 30 years. In this the youngest category i.e. below 29 years, the hearing loss slopes to a moderate loss with 6000 Hz being the most severely affected and recovering slightly at 8000 Hz. The mean NIHL of the left and right ears are very similar for most frequencies with the exception of 1000 Hz, 6000 Hz and 8000 Hz, where the right ear is more affected than the left ear. At 6000 Hz the difference between the right and left ear is greatest, namely 6 dB. These results indicate that the younger gold miner has a more severe hearing loss than other noise-exposed subjects from all types of industries as predicted by Kryter (1985:229). Kryter's predictive curves were drawn up from a combination of many other researchers' results and predicted that the 20 year-old workers could expect a 20 dB mean pure tone threshold. This study shows that the gold miner younger than 29 years would have a mean pure tone threshold of 34 dB.

The implication of this finding is the need for detailed information to be given to workers when they start working in the deep gold mine, about the effect of noise on their hearing, particularly in the early years while the NIHL may not yet be affecting their communication skills. Figure 4. 2 shows the result of the second age category in this sample namely the 30-39 year olds.

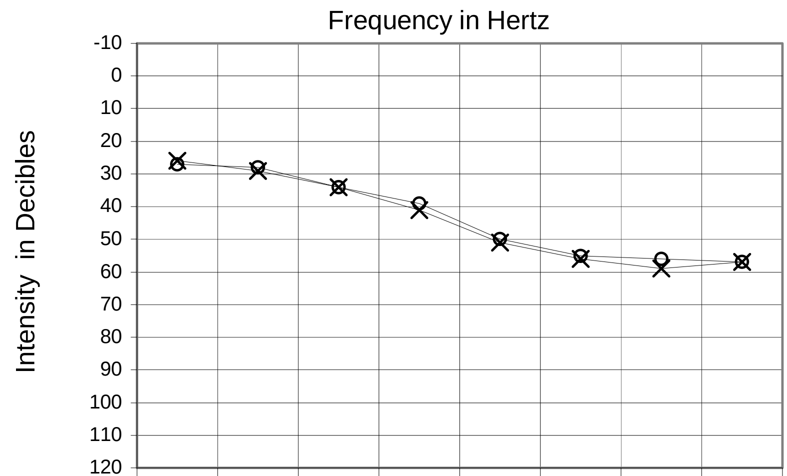


	250	500	1000	2000	3000	4000	6000	8000
Right Ear	27	29	32	36	43	46	50	50
Left Ear	27	28	33	37	44	49	49	49

Figure 4.2 Mean Pure Tone Threshold for ages 30-39 years for gold miners

The results indicate a mild to moderate sloping NIHL with no significant differences between the two ears. The typical “notch” is not evident in this age category. An unexpected and unexplained significant finding in this age category is that the mean pure tone threshold is milder by an average of 2 dB than the younger age category of under 29 year olds. Tempest (1984:59) found that non-noise exposed subjects 30-39 years of age had thresholds of below 5dB for all frequencies. The subjects in this study had thresholds between 27 dB and 50 dB for the frequencies reported. The implication of these results is the severe hearing and communication disability that the gold miner of such a young age must endure, and the probable social implications such as strained marriage relationships.

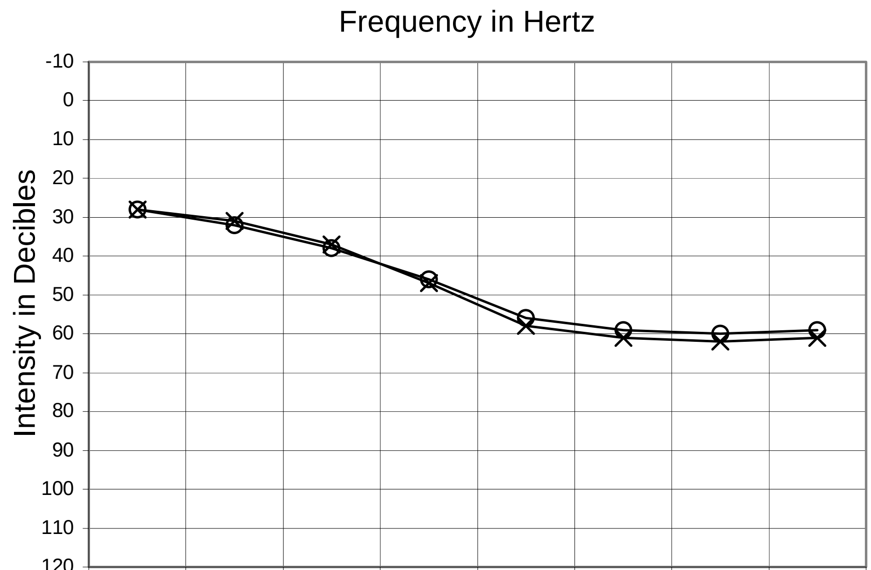
Hessel et al. (1987:365) found a pure tone threshold for this age at 2000 Hz of 5dB and at 6000 Hz of 15dB for the right ear. This study found an average pure tone threshold of 36 dB at 2000 Hz and 50 dB at 6000 Hz. The considerable severity differences are presumably due to the difference in subjects as Hessel et al. used “ routine audiometeric testing of miners appearing for periodic examinations” and state that “miners referred for specific hearing problems were not included” (Hessel et al. 1997:364). Figure 4.3 indicates the mean pure tone thresholds to be expected for gold miners in the age category 40-49 years old.



	250	500	1000	2000	3000	4000	6000	8000
Right Ear	27	28	34	39	50	55	56	57
Left Ear	26	29	34	41	51	56	59	57

Figure 4.3 Mean Pure Tone thresholds for Ages 40-49 years in gold miners

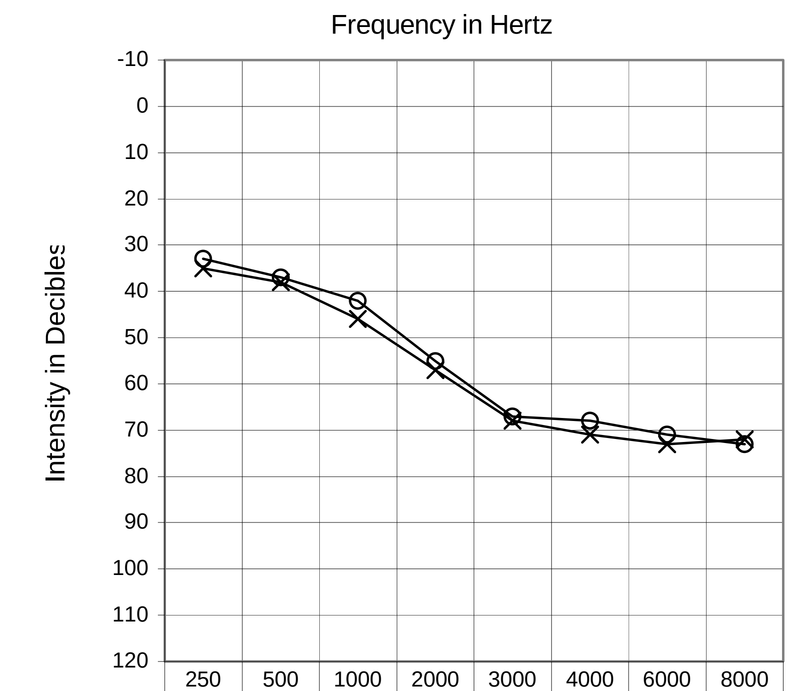
Compared to the previous two age categories the NIHL in the low frequencies have remained largely the same but the hearing ability for frequencies above 1000 Hz has deteriorated by between 4 and 8 dB for the respective frequencies. Tempest (1984:59) indicates the expected hearing threshold of a non-noise exposed 40-49 year old at 1000 HZ to be 0 dB. The extent of the effect of the deep gold mine noise on these 40-49 year old is very evident as their hearing threshold at 1000 Hz is 34 dB. The more marked effect is evident when one compares the expected threshold for 6000 Hz, namely 8 dB (Tempest 1984:59), to these results where the average threshold for 6000 Hz is 57.5 dB. The theoretical implication of these results is that the deterioration of hearing as a result of ARHL begins to deteriorate rapidly after 50 years of age (Tempest 1984:59), while the NIHL in these gold miners has already begun the deterioration at a much younger age. The implications for the social and communicative health of gold miners are great. These miners are at an age when hearing interactions within the working and family environments are important and varied. They already have hearing losses equivalent to that of a 60 year-old non-exposed person (Tempest 1984:59) when they are 40-49 years old. The disability caused by the hearing loss is extensive (Katz 1994:596). Figure 4.4 represents the results for the audiogram to be expected in the age category 50-59 years.



	250	500	1000	2000	3000	4000	6000	8000
Right Ear	28	32	38	46	56	59	60	59
Left Ear	28	31	37	47	58	61	62	61

Figure 4.4 Mean Pure Tone Thresholds for Ages 50-59 years in gold miners

As in the previous age category the thresholds in the frequencies below 1000 Hz are largely similar to the other age categories. The greatest deterioration in hearing ability has occurred at 3000 and 4000 Hz by 6.5 dB in both frequencies. The hearing ability at a high frequency that is least affected in this age category is 8000 Hz. The non-exposed person of this age would expect to have a threshold at 8000 Hz of approximately 22 dB while the subject in this population has a threshold of an average of 60 dB. This again indicates the severity of the disability that the susceptible gold miner has to deal with. The noise exposed worker is expected to have approximately a 35 dB threshold at 4000 Hz (Kryter 1985:229) while the gold miner here has a 60 dB threshold at 4000 Hz for a comparable age. Hessel et al. (1987:365) found a recovery of the thresholds from approximately 37 dB at 3000 Hz to approximately 32 dB at 8000 Hz for the right ear in the equivalent age category. This study finds a mean threshold of 56 dB at 3000 Hz and 59 dB at 8000 Hz. This and the next age category will of course have a large degree of ARHL contributing to the hearing loss. Miller et al. (1998:53) contend that it is evident that aging increases the sensitivity of the ear to NIHL. Figure 4.5 indicates the expected audiogram for the subject older than 60 years.



	250	500	1000	2000	3000	4000	6000	8000
Right Ear	33	37	42	55	67	68	71	73
Left Ear	35	38	46	57	68	71	73	72

Figure 4.5 Mean Pure Tone Thresholds for ages older than 60 years in gold miners.

This indicates that a gold mine worker will have a mean pure tone threshold of 51dB at the age of 65 years as opposed to a worker only affected by ARHL who is reported to have a mean pure tone threshold of 35dB (Kryter, 1985:229). In this age category the first evidence of deterioration in the low frequencies occurs as the thresholds at 250 Hz and 500 Hz deteriorate by 6.5 dB and 6 dB respectively. The deterioration of the miner's hearing is the most marked in this age category as the thresholds for frequencies of 1000 Hz and above deteriorate by between 8 dB and 12.5 dB during these years. Kryter's predictive curves (1985:229) agree with these results. The fact that in all other age categories the gold miner's NIHL was more severe than those in industries reported by Kryter (1985:229), appears to indicate that the NIHL of the gold miner develops differently from other industries but the final NIHL is the same as other industries. The results of graphs 4.1-4.5 are summarized in Table 6 for ease of comparison of the categories.

Table 6. Summary of Mean Pure Tone Thresholds for Age categories in gold miners

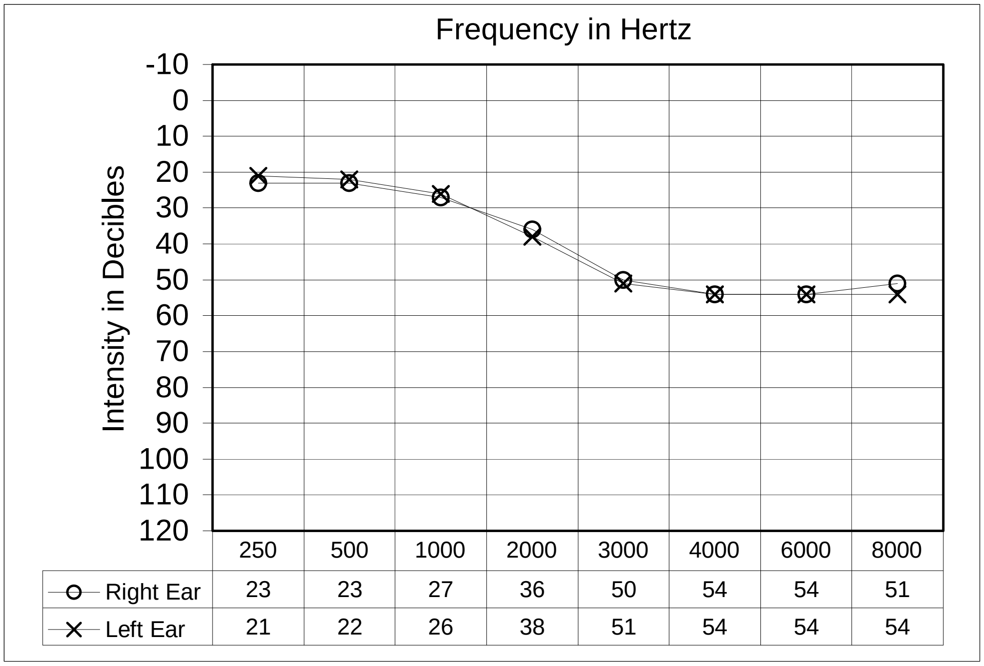
Age	250Hz	500Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
<29	29	30.5	33	33.5	41	41.5	49.5	45
30-39	27	28.5	32.5	36.5	43.5	47.5	49.5	49.5
40-49	26.5	28.5	34	40	50.5	55.5	57.5	57
50-59	28	31.5	37.5	46.5	57	60	61	60
60+	34.5	37.5	44	56	67.5	69.5	72	72.5

If one were to calculate the average yearly deterioration in pure tone threshold from this table one would find .7 dB at 4000Hz and .75dB at 6000Hz. The average yearly pure tone threshold deterioration in white gold miners' was 1.1 dB at 4000Hz and 1.0 dB at 6000Hz in the Hessel et al. study (1987:365). The possible influence of hearing conservation measures could explain the decrease in the average pure tone threshold for the gold miners.

The Duncan test results for age (See Appendix tables 19-26) reveals that the only frequency that is significantly affected by the age of the subject is 1000Hz, and that is only in the youngest and the oldest age categories. The medico-legal factor of interaction between ARHL and NIHL is of interest for the deep gold mining industry as the question arises: How much of the NIHL would have developed as a result of ARHL and how much of the loss is the industry liable for? This question requires further investigation for the deep gold mining industry and the results of this study may contribute to a greater understanding of the answers.

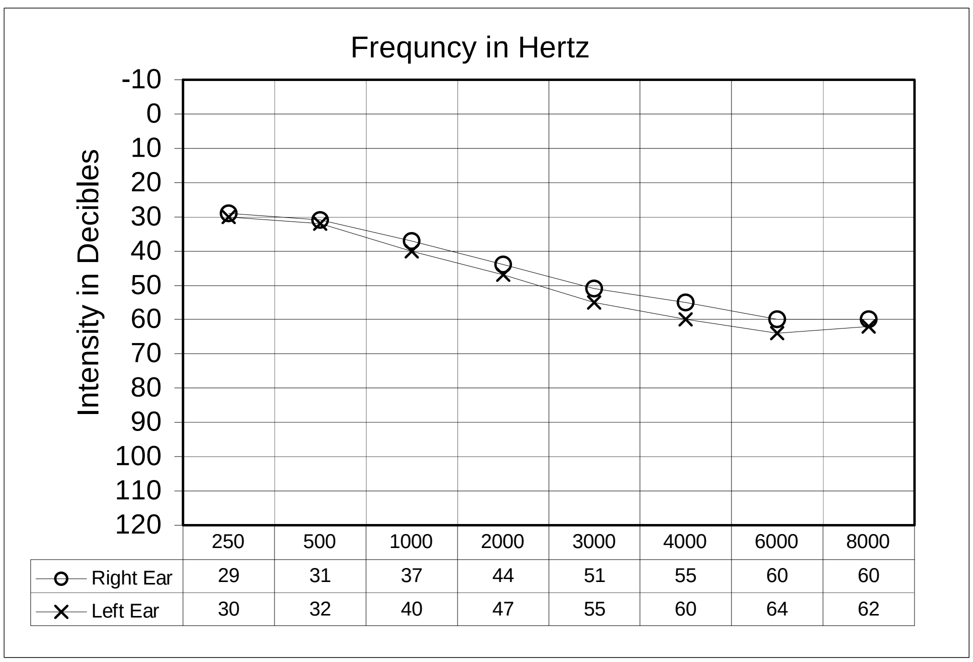
Sub-aim 4: To identify specific audiogram characteristics for different job types of deep gold mine workers.

The third sub-aim of this study was to determine whether the occupation type of the subject influenced the audiogram pattern and if so in what way. Figures 5.1-5.9 represent the mean pure tone thresholds for the nine different occupation types.



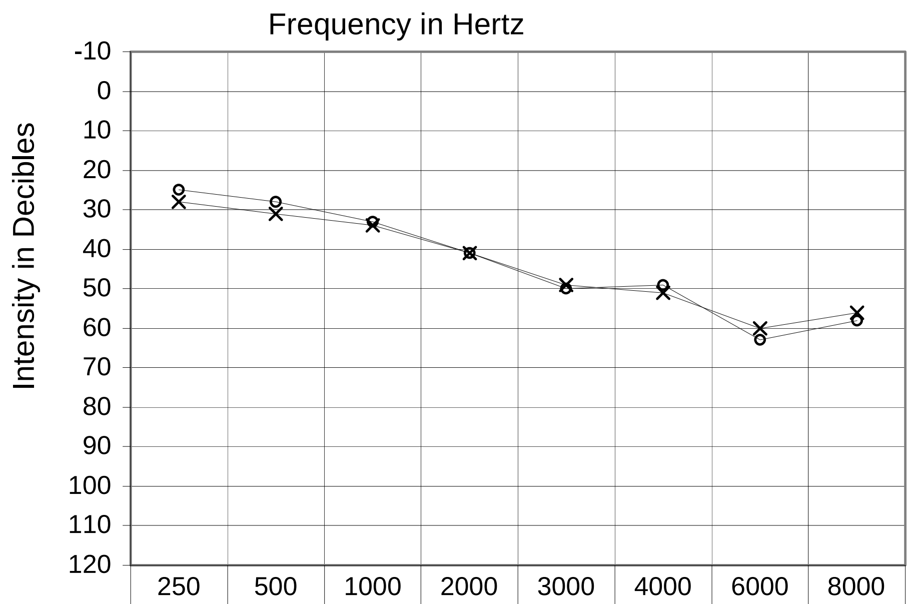
	250	500	1000	2000	3000	4000	6000	8000
Right Ear	23	23	27	36	50	54	54	51
Left Ear	21	22	26	38	51	54	54	54

Figure 5.1 Mean Pure Tone Thresholds For Boilermakers



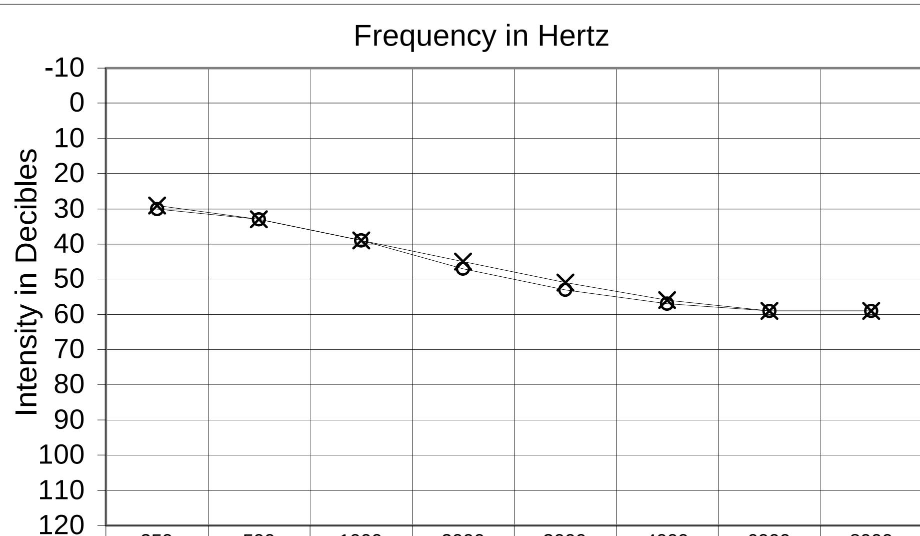
	250	500	1000	2000	3000	4000	6000	8000
Right Ear	29	31	37	44	51	55	60	60
Left Ear	30	32	40	47	55	60	64	62

Figure 5.2 Mean Pure Tone Thresholds For Drillers



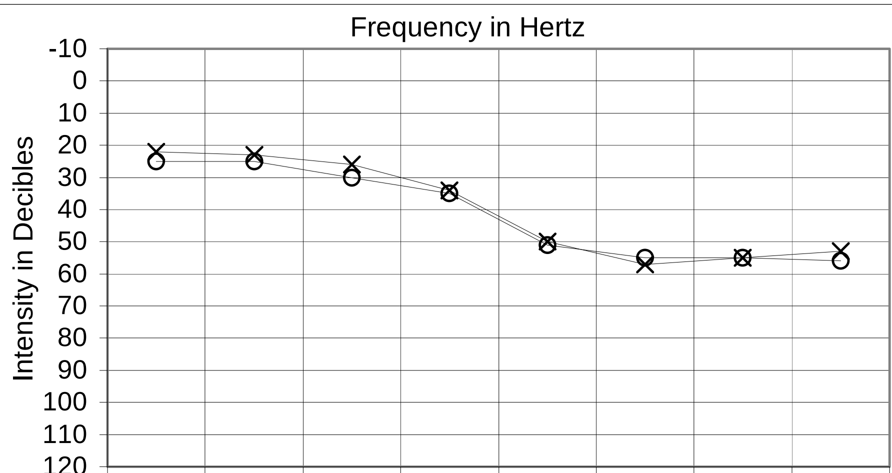
	250	500	1000	2000	3000	4000	6000	8000
Right Ear	25	28	33	41	50	49	63	58
Left Ear	28	31	34	41	49	51	60	56

Figure 5.3 Mean Pure Tone Thresholds For Winch Operators



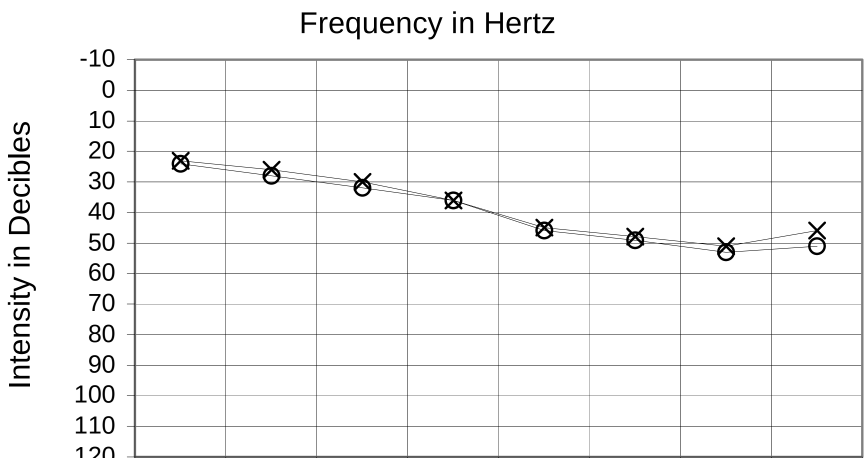
	250	500	1000	2000	3000	4000	6000	8000
Right Ear	30	33	39	47	53	57	59	59
Left Ear	29	33	39	45	51	56	59	59

Figure 5.4 Mean Pure Tone Thresholds For Loco Drivers



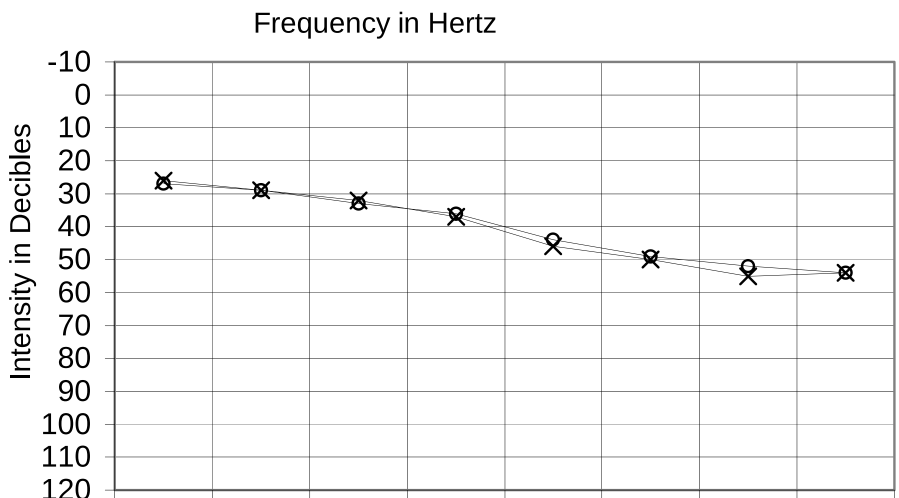
	250	500	1000	2000	3000	4000	6000	8000
Right Ear	25	25	30	35	51	55	55	56
Left Ear	22	23	26	34	50	57	55	53

Figure 5. 5 Mean Pure Tone Thresholds For Shiftbosses



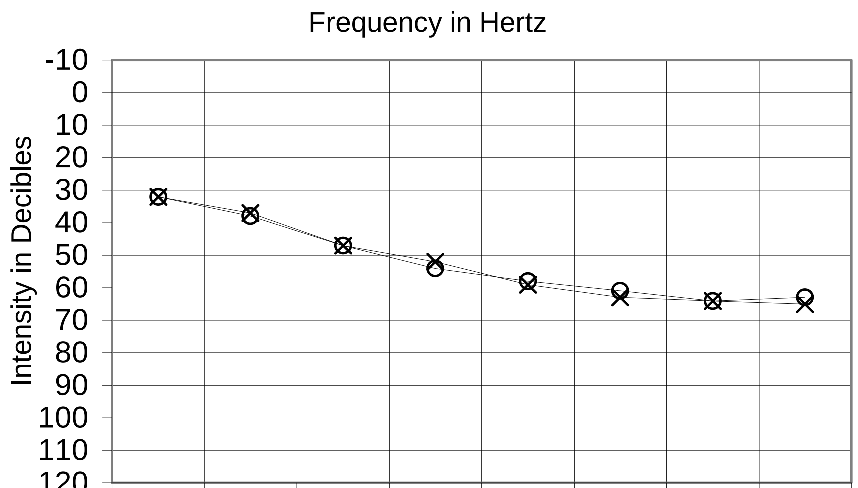
	250	500	1000	2000	3000	4000	6000	8000
Right Ear	24	28	32	36	46	49	53	51
Left Ear	23	26	30	36	45	48	51	46

Figure 5.6 Mean Pure Tone Thresholds For Miners



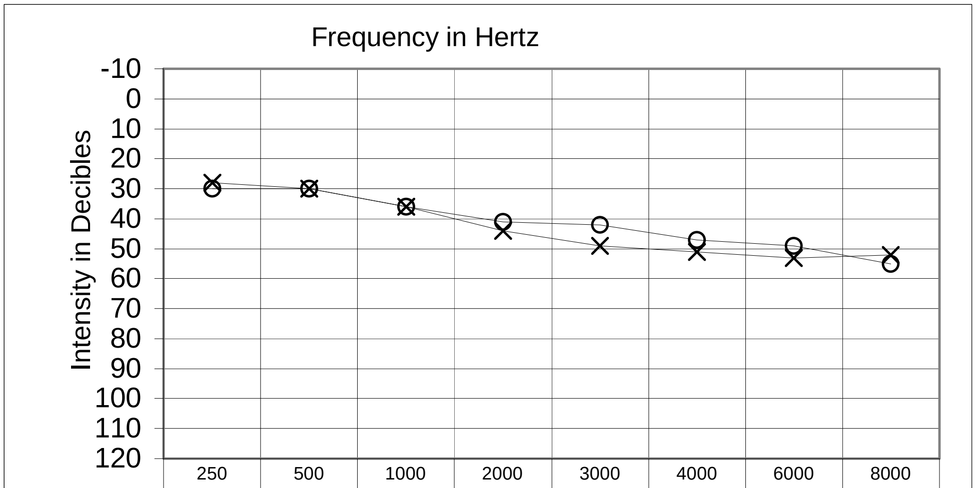
	250	500	1000	2000	3000	4000	6000	8000
Right Ear	27	29	33	36	44	49	52	54
Left Ear	26	29	32	37	46	50	55	54

Figure 5 .7 Mean Pure Tone Thresholds for Stopers



	250	500	1000	2000	3000	4000	6000	8000
Right Ear	32	38	47	54	58	61	64	63
Left Ear	32	37	47	52	59	63	64	65

Figure 5.8 Mean Pure Tone Threshold for Machine Operators



	250	500	1000	2000	3000	4000	6000	8000
Right Ear	30	30	36	41	42	47	49	55
Left Ear	28	30	36	44	49	51	53	52

Figure 5.9 Mean Pure Tone Thresholds for Team Leaders

The results in Figures 5.1–5.9 indicate that the pattern of hearing loss differs according to the occupation type as indicated in the differing audiograms. Boilermakers could expect a moderate loss up to 500 Hz and then severe to profound hearing loss in the 1000-3000 Hz range, deteriorating to a profound loss above 4000 Hz. Both ears show symmetrical results with a slight recovery at 8000 Hz. Drillers have a slightly flatter pattern with the difference between the low and high frequencies being 30 dB. The left ears of drillers are the most affected by NIHL and result in profound flat losses most severely affecting 1000 Hz with no recovery at 8000 Hz. A similarity occurs between the pattern of the mean hearing losses of drillers and shiftbosses in that they both have profound flat losses. However, the shift bosses are more severely affected in the right ear in the low frequencies where the loss is a profound flat loss, while the left ear has a moderate loss with a steep drop off at 2000 Hz and 3000 Hz with no recovery at 8000 Hz.

Stopers have large differences between right and left ear audiograms with a steep drop off at 2000 Hz and no recovery at 8000 Hz. The right ears of stopers have a moderate to profound loss with a very gradual slope while the left ears have a profound, relatively flat losses with dips at 500 Hz and 2000 Hz. Team Leaders and Stopers have very similar hearing losses with only minimal differences of 1-2 dB. The difference in the ears may be due to equipment that is used in this occupation, which exposes the left ear to greater noise doses. Further investigation of the individual ear exposure levels may explain these differences. Loco drivers have mean hearing losses, which are severe to profound with the right ear being more severely affected in the 3000-6000 Hz range and with no recovery at 8000 Hz. Winch operators are most affected in the 6000 - 8000 Hz range, resulting in a severe to profound hearing loss with no recovery at 8000 Hz. The right ear is slightly more affected than the left, particularly at 2000 Hz and 3000 Hz. Machine operators have the most severe mean hearing losses, which are profound flat losses with small zigzag patterns in the low frequencies. Audiograms are symmetrical between the ears.

In summary, in all occupation types both ears are equally affected, with the exception of drillers whose left ears are more severely affected.

The results are further summarized for purposes of comparisons in Table 7.

Table 7. Binaural Mean Pure Tone Thresholds (dB) for Occupation Types

Occupation								
Frequency	250	500	1000	2000	3000	4000	6000	8000
Boilermaker	22	23	26	37	51	54	54	53
Driller	29	31	39	45	53	57	61	61
Winch Operator	26	29	34	41	50	50	61	58
Loco Driver	30	33	39	46	51	57	59	59
Shiftboss	23	24	28	35	50	56	55	55
Miner	24	27	31	36	46	49	52	49
Stoper	26	29	33	36	44	49	53	55
Machine operator	32	38	47	53	59	62	65	64
Team Leader	29	30	36	43	46	50	51	53

Table 7 shows how severely affected by NIHL machine operators are compared to the other occupation types analyzed. These occupation types are exposed to extreme levels of noise, as reported by Franz et al (1997:63).

Further analysis of these results with a Duncan test shows the frequencies that show a significant difference for each occupation type.

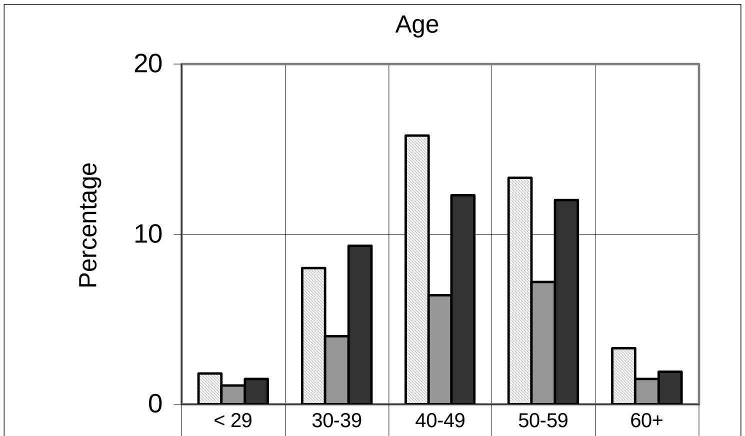
Table 8. Summary of Duncan's test results for occupation types

Miner	Machine operator	Winch operator	Stoper	Driller	Loco Driver	Team Leader	Boilermaker	Shiftboss
250 Hz	250 Hz	4000 Hz	3000 Hz	1000 Hz	1000 Hz	500 Hz	250 Hz	250 Hz
4000 Hz	500 Hz		4000 Hz	2000 Hz	2000 Hz	4000 Hz	500Hz	500 Hz
8000 Hz	1000 Hz			4000 Hz		6000 Hz	1000 Hz	2000 Hz
	2000 Hz							
	3000 Hz							
	4000 Hz							
	6000 Hz							
	8000 Hz							

It is well known that exposure levels and the spectrum of the noise to which workers are exposed have an influence on the NIHL. Franz et al. (1997) report that miners are exposed to noise levels of 103,2 dBA; machine operators to 111,4 dBA; winch operators to levels of 98,3 dBA; stopers are exposed to 102,3 dBA levels; drillers depending on the drill type are exposed on average to 111,4 dBA; loco drivers are exposed to 95 dBA levels; team leaders and shiftbosses depending on the shift are exposed to 100,1dBA on day shift and 104,9 dBA on night shift; boilermakers to approximately 99 dBA. It is interesting to note that occupation types which are exposed to the same levels of noise, for example team leaders and shiftbosses are affected in different frequencies. The explanation for this finding may be in the duration of the noise exposure and/or the time in the subjects' life when he was exposed. Theoretical questions about the interrelatedness of emission frequencies, exposure levels and the affected frequencies need further investigation. A severe shortcoming of this section of the study is the lack of information about the career of each subject. The occupation type reported by a subject at the time of the interview was the assumed occupation type, but he may have been exposed to other occupation type noise during his working career. The clinical implication is for more detailed case history taking to facilitate this type of research, within the confines of practicality and costs.

Sub-aim 4: To determine the incidence of reported tinnitus in gold miners

The fourth sub-aim moves on to the non-auditory effects of NIHL, specifically the incidence of tinnitus in the deep gold mining population. Figure 6 indicates that the majority of tinnitus sufferers are in the age range 30-60 years.



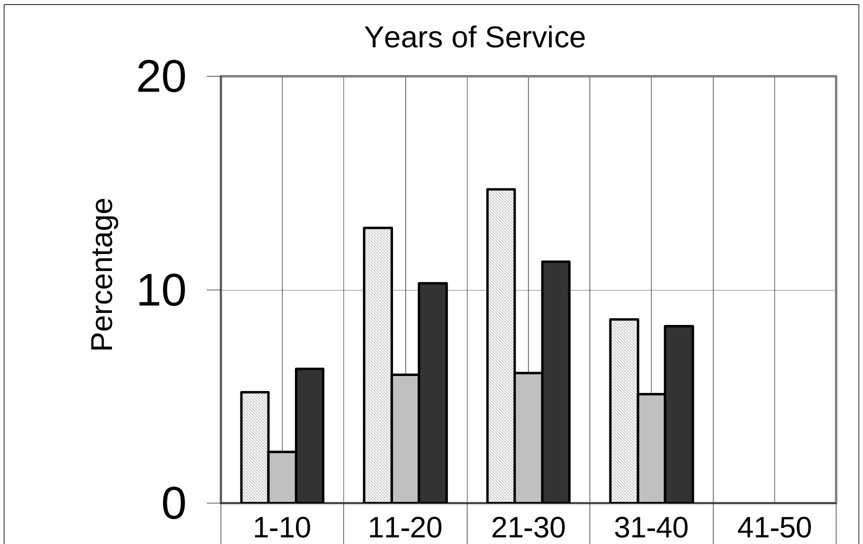
	< 29	30-39	40-49	50-59	60+
Yes	1.8	8	15.8	13.3	3.3
Sometimes	1.1	4	6.4	7.2	1.5
No	1.5	9.3	12.3	12	1.9

Figure 6. Age and prevalence of tinnitus in deep gold miners

Most reports on the etiology of tinnitus are that the most common cause of tinnitus is NIHL but there is large variability in the reported incidence that ranges from 5%-80% (Dancer 1992:270). Coles (in Dancer, 1992:273) found an incidence of 21-22% in NIHL subjects under 60 years old, while subjects over 60 years old, had an incidence of 33%. Axelsson (in Dancer 1992:270) found that 54-58% of miners suffered from tinnitus.

The way that one interprets whether or not a subject suffers from tinnitus will determine how one reads the results of this study. If one assumes that the answers “yes” and “sometimes” both mean that the subject suffers from the effects of tinnitus, then the results from both of these categories must be added together to ascertain the incidence of tinnitus in the deep gold mining population. Working on this assumption, this study found that tinnitus was present in 57.8 % of subjects under 60 years old, while in subjects over the age of 60 years of age the incidence was 4.8 %. These percentages confirm Axelsson’s (1992) findings. The present study found that at age 40-49 there was the highest incidence of reported tinnitus, namely 22.2%. This is significant in that the worker is very active in his social and working life at this stage and the tinnitus could contribute significantly to communicative difficulties he may experience. The age of the worker is closely related to the years that he has worked.

Figure 7 shows the relationship between the years of service of the subjects and the incidence of tinnitus.

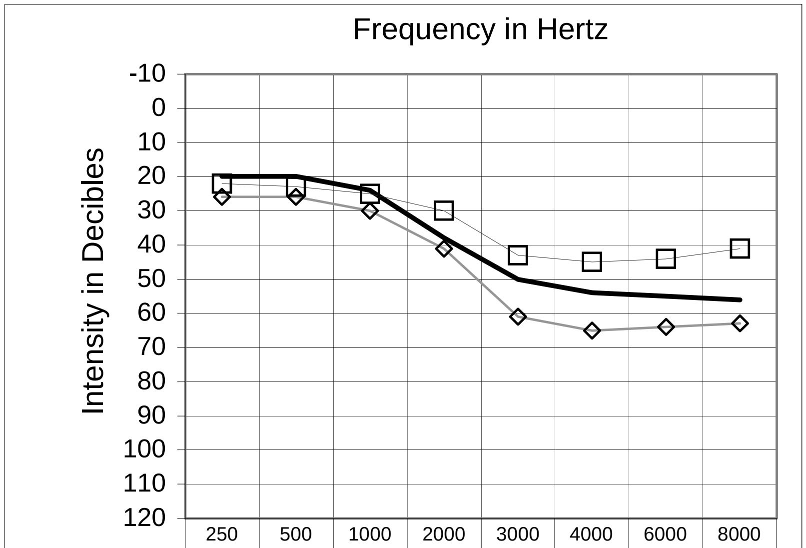


	1-10	11-20	21-30	31-40	41-50
Yes	5.2	12.9	14.7	8.6	0
Sometimes	2.4	6	6.1	5.1	0
No	6.3	10.3	11.3	8.3	0

Figure 7. Years of service and prevalence of tinnitus in deep gold miners

The present study found that those who had worked for between 21 and 30 years had the highest reported incidence of the presence of tinnitus namely 20.8%. Axelsson (in Dancer, 1992:270) found that the incidence of tinnitus was 34% in a population exposed to noise for up to ten years. After this the incidence was reasonably constant in the groups where exposure was 11-30 years, namely 54%, and in the group exposed for 31-50 years it was 50%. The present study found that the group with up to ten years of service had an incidence of 7.6%; 11-30 years had an incidence of 39.7% and the group with exposure of 31-50 years had an incidence of 13.7%. The differences in results may be due to different questioning methods in the different studies or may be influenced by noise type in different industries.

Figure 8 represents a binaural audiogram in relation to the reported presence of tinnitus.



	250	500	1000	2000	3000	4000	6000	8000
Yes	20	20	24	38	50	54	55	56
Sometimes	22	23	25	30	43	45	44	41
No	26	26	30	41	61	65	64	63

Figure 8. Binaural Mean Pure Tone Threshold and tinnitus in deep gold miners

The significance of the hearing threshold in relation to tinnitus is well known. “The hearing threshold is the most important determinant for tinnitus incidence.” (Axelsson in Dancer, 1992:273). Figure 8 indicates that gold miners with milder hearing losses only sometimes experience tinnitus. Those who report the presence of tinnitus have a mild to moderate sloping hearing loss. It appears that the more severe the hearing loss the less workers suffer from the presence of tinnitus. This is seen in the group that reports that they do not suffer from tinnitus and has a mild to severe sloping hearing loss.

Axelsson (1992) and Coles (in Dancer, 1992:273) found that with increasing hearing loss the incidence of tinnitus increases. also found that with increasing hearing loss the incidence of tinnitus increased. This study found differently, the more the severe the hearing loss, the more subjects answered “no” to the question regarding tinnitus. In all the areas analyzed for tinnitus thus far it is evident that the older the worker, and therefore also the longer he has worked and the more severe his hearing loss, the less likely he is to suffer from the presence of tinnitus. This does not agree with other studies and the explanation may be twofold. Firstly, the manner of questioning may have differed from that employed in other studies. Secondly, the type of noise that

gold miners are exposed to may have unique properties and results. This aspect of NIHL in gold miners was a minor aspect of the study and is minor in the diagnostic audiology interview. The implication for clinical audiology is to give more attention to the questioning technique and to the effects that tinnitus has on the gold miner.
A final investigation with regards to tinnitus is the relationship to the occupation type of the subject. Table 9 indicates the incidence of reported tinnitus for different occupation types.

Table 9. The Incidence of tinnitus (%) in different occupation types of gold miners.

	Yes	Sometimes	No
Boilermaker	39.58	31.25	29.17
Driller	41.18	11.76	47.06
Winch operator	36.36	15.15	48.48
Loco driver	55.56	13.89	30.56
Shiftboss	44	24	32
Miner	43.06	19.44	37.5
Stoper	38.89	22.22	38.89
Machine operator	42.03	11.59	46.38
Team Leader	58.33	16.67	25

The table indicates that the occupation type with the highest incidence of tinnitus is that of team leader. More than half of the team leaders and loco drivers in this population reported the presence of tinnitus. The occupation type that has the lowest incidence of tinnitus is that of winch operator. Drillers and machine operators also had low incidences of tinnitus. If one assumes that an answer of “yes” as well as one of “sometimes” indicates that subjects suffer from the effects of tinnitus, more than 50 % in each occupation type may be seen to suffer from tinnitus. Once again the weakness of this analysis is that we are not sure of the other occupational exposure that the subjects may have had during their working careers.
Coles (in Dancer, 1992:275) regards the diversity of results when studying tinnitus and NIHL as being due to the diversity of investigation methods and subject choices. The significant result from the present study that a large percentage of the subjects suffered from tinnitus to some degree, may indicate the need on the part of the deep gold mining industry to take greater precautions in their hearing conservation programmes. Coles (in Dancer 1992:274) puts it: "NIHL is a completely unnecessary

condition, except for accidental circumstances", and we could add that tinnitus is a completely unnecessary condition.

Axelsson (1992) states, “even if tinnitus is completely subjective, it should be considered in compensation claims, because it frequently increases the total handicap to a considerable extent.” The implication for the audiologist is the importance of including tinnitus retraining or special fitting of hearing aids in the total treatment of the gold miner to ensure that communication health and hearing health are achieved.

Sub-aims 5: To determine the incidence of occurrence of vertigo/balance and nausea problems in deep gold mine workers.

These two aspects are included in one question in the interview for and are therefore reported as one section of the results.

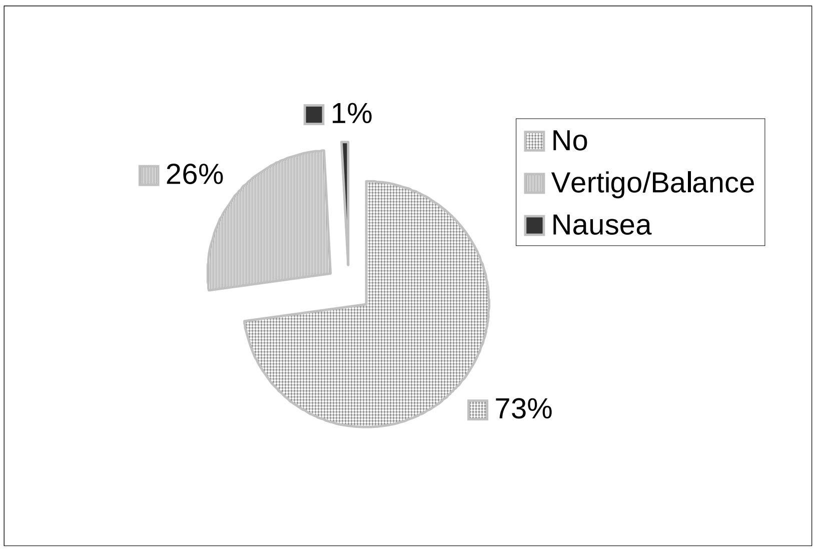


Figure 9. Incidence of vertigo/balance and nausea symptoms in deep gold miners

Figure 9 indicates that Vertigo/Balance and Nausea symptoms are not experienced by 73% of the subjects. However, 26% do experience vertigo/balance problems and less than 1% experience nausea problems. These non-auditory effects of NIHL in gold miners may be contributing factors to the disability experienced by subjects and have implications for audiologists in treating these subjects, such as having sufficient knowledge to differentially diagnose non-auditory side effects of NIHL from neurological symptoms.

CONCLUSION

In answering the research question of this study, evidence was found of characteristics of NIHL in gold miners, which can be useful in the audiological clinical setting. These characteristics are:

- A mean pure tone threshold ranging from 33.5dB to 61dB, depending on how long the miner has been exposed to the noise.
- The occupation type will result in certain threshold patterns as described previously.
- The probability of a gold miner suffering from tinnitus can be up to 20.8% if he has worked for 30 years.

The clinical value of knowing these results is that the audiologist is better equipped to deal with diagnostic testing of this population. This is because the audiologist is more aware of the expected audiograms based on years of service; age and occupation type and will be more confident in dealing with malingerers and hopefully of reducing the need for expensive tests such as Auditory Brainstem Response audiometry. The audiologist, in the clinical setting, will also be more alerted to the presence, onset and type of tinnitus as well as to the need for good follow up and treatment of the NIHL in the gold miner through all possible channels. Successful hearing aid fitting and aural rehabilitation of gold miners are important aspects of the audiologist's role in the team dealing with NIHL subjects. These results have important clinical value in that the audiologist is better able to anticipate the needs of this population for aural rehabilitation. The theoretical implications of the results of this study are that when noise emission and exposure levels exceed 90dBA as they are reported to do in many of the areas in the deep gold mining environment, then the typical notch of NIHL is not evident on the audiogram and the shape of the audiogram becomes more like that of ARHL, and other frequencies such as 2000-6000Hz are as severely affected as the 4000Hz notch. The effects of mechanical overdrive of the cochlear hair cells may be the cause of the severity of the losses in these excessively high levels of noise. The factors of toxins, heat and physical exercise may contribute to the severity of the degree of loss in these subjects.

The implications for conservation of gold miners' hearing would be the need for greater awareness in certain occupations and more thorough information being given for these workers as well as scheduling of shorter work shifts. The use of effective hearing protection devices is vital when one looks at the effect on hearing in these occupation types. Compensation for the effects of tinnitus is the practice in some countries. However, the complete subjectivity of the condition makes evaluation extremely difficult. Given that NIHL is regarded as the prime etiological factor for tinnitus, it becomes important to alert workers to the possible early warning signs of hearing loss and the probability of developing tinnitus if good conservation methods are not adhered to.

Further research needs to include more investigation into controlled occupation types and the resulting hearing loss as well as improved questioning techniques and protocols for the presence, type and onset of tinnitus. The setting up of a database for all workers and the record of their pre-employment hearing thresholds, their annual hearing screening and any further diagnostic audiology testing would be a helpful tool in controlling the hearing conservation programmes. It is beyond the scope of this article, but relating Franz et al's (1997) findings regarding exposure levels, to the findings of this study would shed more light on the causes of the typical characteristics of hearing loss in deep gold mine workers. Comparisons of audiograms of workers in other industries would establish which characteristics are unique to gold mining hearing loss. More information on the conservation procedures and referral protocols for specific time periods and their influence on hearing levels, would also be of interest for further research. Due to the extreme levels of noise, research into possible preventative measures for conservation purposes as suggested by Canlon et al. (1996:172) and Henderson et al. (1996:150), where prior exposure to low level noise or sound conditioning may save the mining industry on compensation claims and on miners hearing.

The limitations of this study are the lack of information regarding the subjects' exact exposure history. A further limitation is the fact that only pure tone thresholds were available to measure the NIHL of these subjects. It would be very important therefore not to use the findings too categorically and to verify the findings through further, controlled research. The implication is also to improve the questioning methods in case history taking during diagnostic audiology procedures. The problem with both conservation and further questioning in diagnostic audiology is that these take time and time is money for both the mining industry and the audiology profession. Other limitations are the lack of information about pre-employment hearing status for these subjects and any information about hearing conservation and its effect on the results. The implications for the mining industry are numerous if further research could be carried out in this area.

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APPENDIX

Table 10. Duncan' Multiple Range Test for 250Hz

Duncan Grouping	*Mean*	*N*	*Service*
A	*40.227*	*11*	*41-50*
B *B*	*29.009*	*116*	*31-40*
B *B*	*28.114*	*167*	*21-30*
B *B*	*27.383*	*149*	*11—20*
B *B*	*26.786*	*77*	*1-10*

Table 11. Duncan' Multiple Range Test for 500Hz

Duncan Grouping	*Mean*	*N*	*Service*
A	*42.500*	*11*	*41-50*
B *B*	*32.478*	*116*	*31-40*
B *B*	*32.063*	*167*	*21-30*
B *B*	*30.034*	*149*	*11—20*
B *B*	*27.792*	*77*	*1-10*

Table 12. Duncan' Multiple Range Test for 1000Hz

Duncan Grouping		*Mean*	*N*	*Service*
	A	*57.045*	*11*	*41-50*
	B *B*	*39.332*	*116*	*31-40*
C *C*	*B* *B*	*38.626*	*167*	*21-30*
C *B*	*B*	*35.450*	*149*	*11—20*
C *C*		*31.688*	*77*	*1-10*

Table 14. Duncan' Multiple Range Test for 2000Hz

Duncan Grouping		*Mean*	*N*	*Service*
	A	*71.591*	*11*	*41-50*
	B *B*	*48.664*	*116*	*31-40*
C *C* *C*	*B* *D*	*45.210*	*167*	*21-30*
C *B*	*D*	*40.419*	*149*	*11—20*
	D *D*	*35.065*	*77*	*1-10*

Table 15. Duncan' Multiple Range Test for 3000Hz

Duncan Grouping		*Mean*	*N*	*Service*
	A	*76.818*	*11*	*41-50*
	B *B*	*58.296*	*113*	*31-40*
C *C*	*B*	*53.906*	*160*	*21-30*
C	*B* *D*	*48.757*	*138*	*11—20*
	D *D*	*41.042*	*72*	*1-10*

Table 16. Duncan' Multiple Range Test for 4000Hz

Duncan Grouping		*Mean*	*N*	*Service*
	A	*76.818*	*11*	*41-50*
	B *B*	*61.370*	*115*	*31-40*
	B *B*	*57.739*	*165*	*21-30*
C *C*	*B*	*53.104*	*149*	*11—20*
C		*46.006*	*77*	*1-10*

Table 17. Duncan' Multiple Range Test for 6000Hz

Duncan Grouping		*Mean*	*N*	*Service*
	A *A*	*73.056*	*9*	*41-50*
B *B*	*A*	*63.234*	*109*	*31-40*
B *B*		*60.943*	*159*	*21-30*
B *B*	*C*	*55.417*	*138*	*11—20*
	C *C*	*50.109*	*69*	*1-10*

Table 18. Duncan' Multiple Range Test for 8000Hz

Duncan Grouping		*Mean*	*N*	*Service*
	A	*74.000*	*10*	*41-50*
	B *B*	*62.656*	*112*	*31-40*
	B *B*	*60.239*	*165*	*21-30*
C *C*	*B*	*55.218*	*149*	*11—20*
C		*48.780*	*75*	*1-10*

Table 19. Duncan' Multiple Range Test for 250Hz

Duncan Grouping	*Mean*	*N*	*Age*
	32.054	*28*	*60+*
A *A*	*29.135*	*159*	*50-59*
A *A*	*28.229*	*24*	*1-29*
A *A*	*27.883*	*124*	*30-39*
A *A*	*26.919*	*185*	*40-49*

Table 20. Duncan' Multiple Range Test for 500Hz

Duncan Grouping	*Mean*	*N*	*Age*
A *A*	*33.711*	*159*	*50-59*
A *A*	*33.393*	*28*	*60+*
A *A*	*29.878*	*185*	*40-49*
A *A*	*29.738*	*124*	*30-39*
A	*28.958*	*24*	*1-29*

Table 21. Duncan' Multiple Range Test for 1000Hz

Duncan Grouping		*Mean*	*N*	*Age*
	A *A*	*41.339*	*28*	*60+*
	A *A*	*41.179*	*159*	*50+59*
B *B*	*A*	*36.286*	*185*	*40-49*
B *B*		*33.685*	*124*	*30-39*
B		*31.979*	*24*	*1-29*

Table 22. Duncan' Multiple Range Test for 2000Hz

Duncan Grouping		*Mean*	*N*	*Age*
	A *A*	*53.393*	*28*	*60+*
	A	*49.528*	*159*	*50-59*
	B *B*	*42.500*	*185*	*40-49*
C	*B*	*37.681*	*124*	*30-39*
C *C*		*33.333*	*24*	*1-29*

Table 23. Duncan' Multiple Range Test for 3000Hz

Duncan Grouping		*Mean*	*N*	*Age*
	A *A*	*63.646*	*24*	*60+*
B *B*	*A*	*58.523*	*154*	*50-59*
B	*C* *C*	*51.620*	*179*	*40-49*
D	*C*	*44.161*	*115*	*30-39*
D *D*		*40.114*	*22*	*1-29*

Table 24. Duncan' Multiple Range Test for 4000Hz

Duncan Grouping	*Mean*	*N*	*Age*
A *A*	*63.704*	*27*	*60+*
A *A*	*60.621*	*157*	*50-59*
A	*57.092*	*185*	*40-49*
B *B*	*49.032*	*124*	*30-39*
B	*41.875*	*24*	*1-29*

Table 25. Duncan' Multiple Range Test for 6000Hz

Duncan Grouping		*Mean*	*N*	*Age*
	A *A*	*68.043*	*23*	*60+*
	A *A*	*62.961*	*152*	*50-59*
B *B*	*A*	*59.403*	*175*	*40-49*
B	*C* *C*	*51.228*	*112*	*30-39*
	C	*48.452*	*21*	*1-29*

Table 26. Duncan' Multiple Range Test for 8000Hz

Duncan Grouping		*Mean*	*N*	*Age*
	A *A*	*69.554*	*28*	*60+*
B *B*	*A*	*61.520*	*153*	*50-59*
B	*C* *C*	*59.427*	*184*	*40-49*
D *D*	*C*	*50.821*	*123*	*30-39*
D		*45.109*	*23*	*1-29*