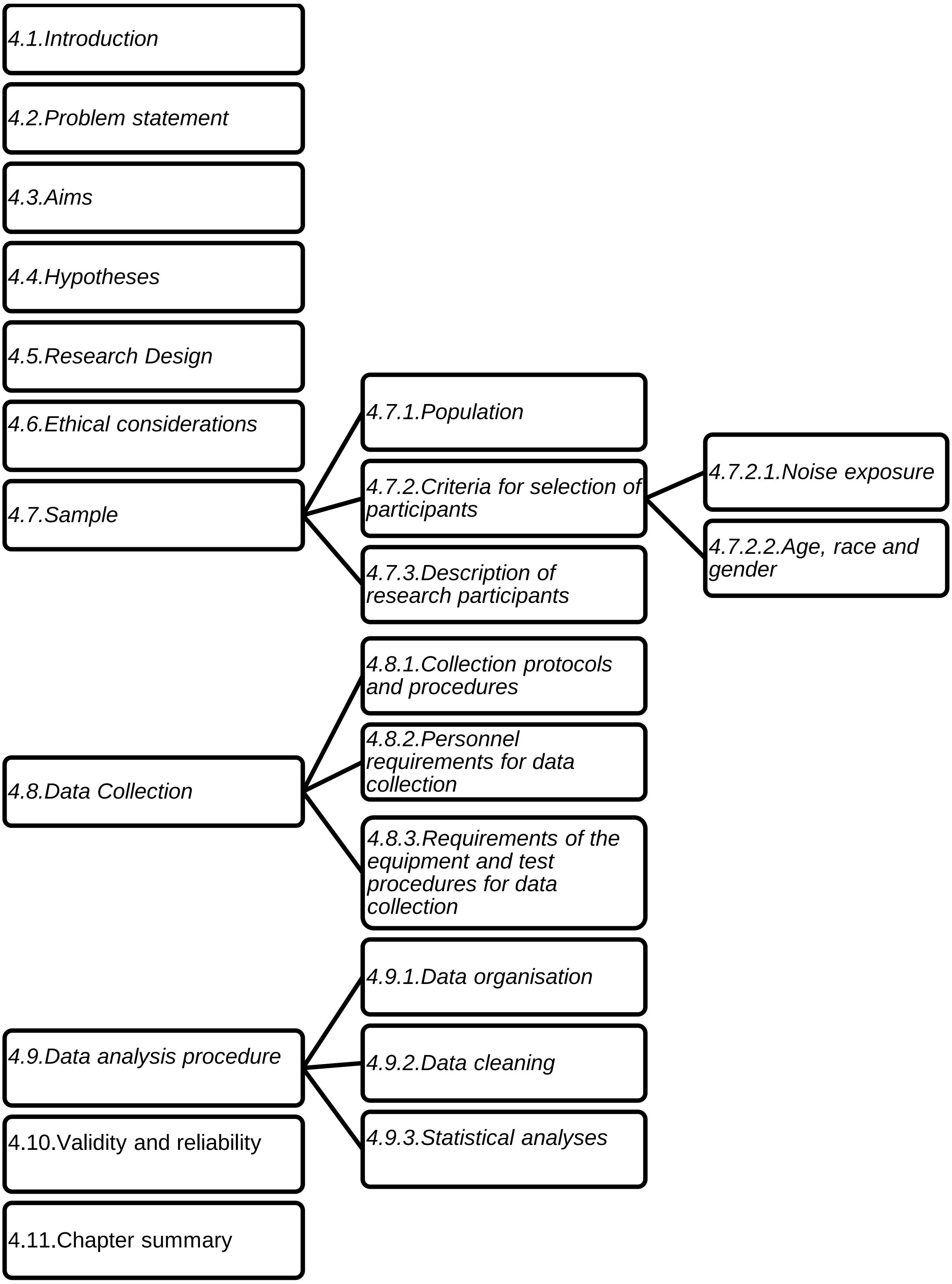
4. Methodology



4.1. Introduction

In the previous chapters a foundation of academic research was established. Different research into the field of noise-induced hearing loss (NIHL) was presented. The previous chapters aimed to frame NIHL within the context of research into the prevalence and incidence of NIHL worldwide. Research results highlighting the mechanism of NIHL and the co-variables that influence hearing were described. The effects of noise and damage risk criteria were also discussed and controversies were noted and deliberated. Within the framework of NIHL as a compensable disease, different definitions of hearing impairment were considered. The empirical part of this study set out to describe the prevalence and nature of NIHL and to evaluate the criteria for determining hearing impairment in South African gold miners.

Figure 4.1 depicts the research process followed throughout the study.

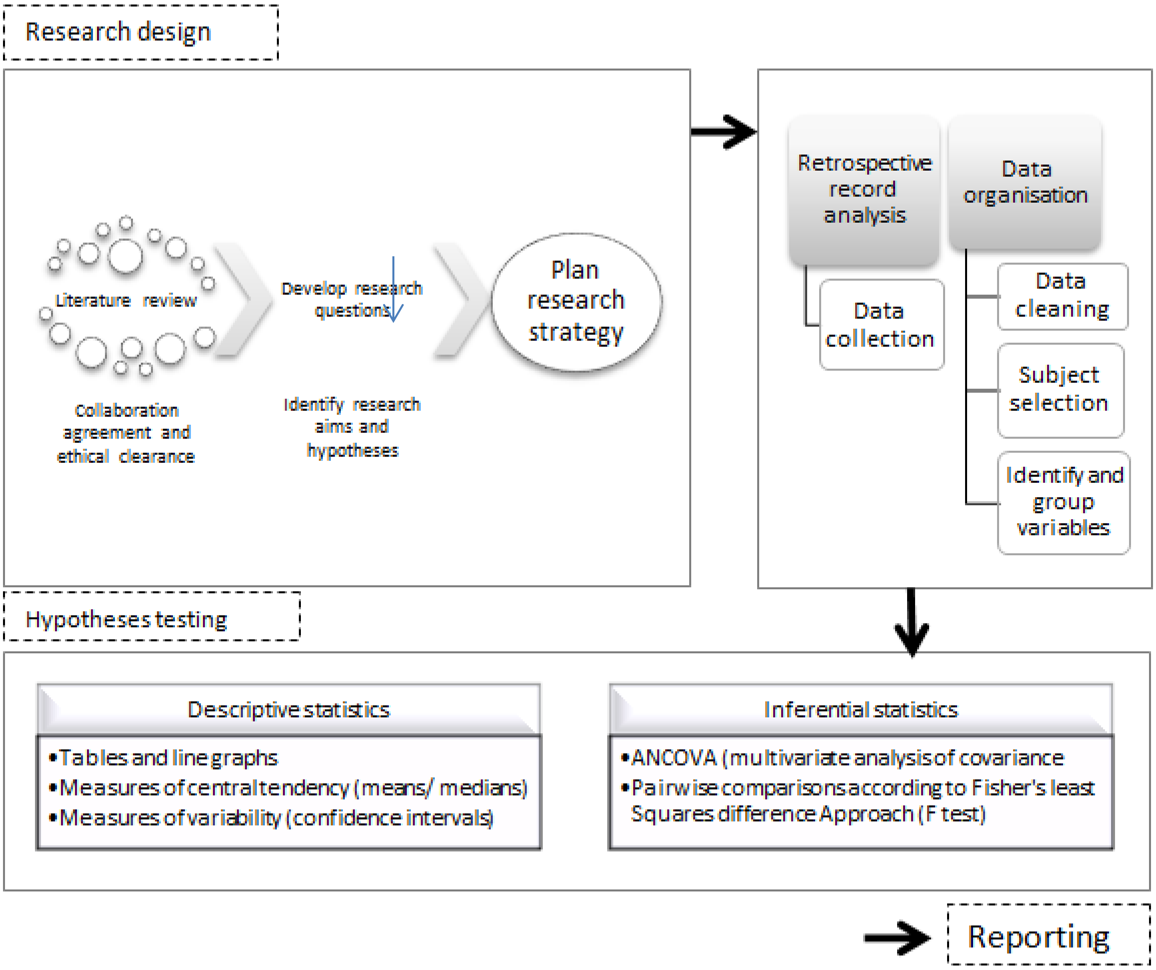


Figure 4-1 Research Design

4.2. Problem statement

In the previous chapters a foundation for academic research was established. Different aspects relating to noise-induced hearing loss (NIHL) were presented. Taking into account the dearth of research describing NIHL in large populations, differing opinions about the effect of variables (such as age, race and gender) co-existing with NIHL, many controversies surrounding the effect and measurement of noise, the calculation of hearing impairment, and the rate of hearing threshold deterioration in the mining community of South Africa, the research question shapes around what the nature and degree of NIHL is in a group of gold miners and whether the current criteria for characterising hearing impairment in South Africa is valid for identifying NIHL in gold miners.

The research questions that this study addresses are the following:

- What is the prevalence and degree of hearing loss in the group of gold miners?
- What is the prevalence and degree of hearing loss as a function of age, race and gender?
- What is the prevalence and degree of hearing loss as a function of occupation/ noise-exposure level?
- What is the combined effect of various biographical, environmental and work-related variables on hearing status?
- How effective is the sensitivity of the current impairment criteria to identify NIHL and compare it to other existing criteria?

4.3. Aims

The main aim of this study is to describe the prevalence and degree of NIHL considering demographic and environmental variables and to evaluate the criteria for determining hearing impairment in South African gold miners.

The following sub-aims have been formulated in order to realise the main aim of the study:

Sub aim one: To describe the prevalence and degree of hearing loss

Sub aim two: To describe the prevalence and degree of hearing loss as a function of age, race and gender

Sub aim three: To describe the prevalence and degree of hearing loss as a function of occupation / noise-exposure level

Sub aim four: To assess the combined effect of various biographical, environmental and work-related variables on hearing status

Sub aim five: To evaluate the effectiveness of the current impairment criteria to identify NIHL and compare it to other existing criteria

4.4. Hypotheses

In research literature the term “hypothesis” can either refer to a consequence of the research problem and as such a mere assumption, or it can refer to a statistical hypothesis that can be tested (Leedy & Ormrod, 2001). The statistical hypothesis can be defined as a predictive statement that relates an independent variable to some dependent variable, capable of being tested by scientific methods (Kothari, 1990). Statistical tests are designed to test a null hypothesis, which is a prediction that there will be no change (Brewer & Stockton, 2010). A null hypothesis is designated by H_0. An alternative hypothesis is the complement of the null hypothesis and would predict a direction of change or difference (Brewer & Stockton, 2010) (would be designated as H_1). Directional hypotheses for this study were formulated for hypotheses where the literature review indicated a specific direction (for aims 1, 2, 3, and 5).

The following hypotheses were formulated from the research aims (null hypothesis ($H_0 0$) or alternative hypothesis (H_a)):

$H1_0$	There is no difference between the prevalence and degree of hearing loss for the gold miners exposed to high levels of occupational noise and a control group.
$H1_a$	Gold miners exposed to high levels of occupational noise will have a higher prevalence and greater degree of hearing loss than a control group not exposed to occupational noise.
$H2i_0$	There is no difference between the prevalence and degree of hearing loss for gold miners of different ages.
$H2i_a$	Gold miners of greater age will have a higher prevalence and a greater degree of hearing loss than younger gold miners.
$H2ii_0$	There is no difference between the prevalence and degree of hearing loss for male and female gold miners.
$H2ii_a$	Male gold miners will have a higher prevalence of and a greater degree of hearing loss than their female counterparts.
$H2iii_0$	There is no difference between the prevalence and degree of hearing loss for gold miners of different races.
$H2iii_a$	White gold miners will have a higher prevalence and a greater degree of high frequency hearing loss than their black counterparts.
$H3_0$	There will be no difference in prevalence and degree of hearing loss as a function of occupation / noise-exposure level.
$H3_a$	Gold miners exposed to more occupational noise for a longer period will have a higher prevalence and a greater degree of hearing loss than participants exposed to lower levels of occupational noise.
$H4_0$	There will be no difference in degree of hearing loss as a function of different biographical, environmental or work-related variables.
$H4_a$	Hearing status will be influenced by different biographical, environmental or work-related variables.

$H5_0$ The current impairment criteria (RSA) are effective in identifying NIHL.

$H5_a$ The current impairment criteria (RSA) are not effective in identifying NIHL.

4.5. Research Design

The research design provides the logical structure that guides the investigation to address the research problems and answers the research questions (DeForge, 2010). Methodological decisions (such as data collection and data analyses) are informed and guided by the selected research design.

The research conducted for this study is exploratory and descriptive, utilising a non-experimental, observational design. Observational designs are referred to as non-experimental because the investigator does not intervene or manipulate variables (DeForge, 2010). Non-experimental research designs are grounded in an understanding of causal relations through observation, description and empirical testing (Maxwell & Satake, 2006).

A retrospective cohort design was used for the research conducted through this study. Cohort refers to any group of individuals with shared characteristics such as the same age, gender, occupational noise-exposure level or occupation. In a retrospective cohort design the investigator defines the sample population and collects data about both exposures and outcomes that have occurred in the past (such as the audiogram data used for this study, collected between 2001 and 2008) (DeForge, 2010; Ho, Peterson, & Masoudi, 2012). The data for this study were collected over a number of years by the occupational health department at the West Wits operation of the AngloGold Ashanti Gold Mine in the Witwatersrand. An advantage of such a retrospective study is that it is financially more feasible and can be completed in a shorter time frame (Maxwell & Satake, 2006) since past records with known outcomes are used. A retrospective design also made it possible to study an extremely large sample (Ho, Peterson, & Masoudi, 2012). A limitation of this retrospective cohort design was that the investigator did not have control over certain confounding variables. In order to control for the known confounding variables, such as age, statistical methods were employed and will be described in section 4.9.3.

Descriptive research involves attempting to define or measure a particular phenomenon, in this case hearing loss in gold miners (Dane, 1990). The research was exploratory in nature in order to determine whether a relationship existed among several variables under scrutiny. In this regard probability statistics that allow for the determination of test accuracy according to the proportion of all test results, both positive and negative, were used (Maxwell & Satake, 2006). The research was quantitative in nature. Quantitative research refers to the systematic empirical investigation of phenomena via statistical and mathematical techniques (Given, 2008). The objective of quantitative research is to develop and employ hypotheses pertaining to phenomena. The process of measurement is central to quantitative research because it provides the fundamental connection between empirical observation and mathematical expression of quantitative relationships (Given, 2008).

4.6. Ethical considerations

The guiding value for researchers is integrity, which is expressed in a commitment to the search for knowledge and in the honest and ethical conduct of research and dissemination and communication of results (MRC, 2002). The following ethical principles were adhered to during the course of the research project: the principle of respect and protection and the principle of scientific and academic professionalism (MRC, 2008).

Informed consent was obtained from the specific gold mine prior to the commencement of this project. Approval was obtained from the relevant authorities (attached as Appendix A). An agreement exists between the gold mine authorities and the mine workers that information on their hearing (audiograms and noise-exposure levels) may be used in possible research projects.

Information obtained in the course of this research study that revealed the identity of a participant or an institution was treated as confidential. Furthermore mineworkers' information (audiograms, work history and other relevant information) were used anonymously. A specific code was, where necessary, allocated to research participants for data processing and the names of participants were never used in data analyses or reporting.

In order to adhere to the principle of scientific and academic professionalism and accountability, the researcher did not fabricate data, misrepresent or intentionally mislead others in the nature of the findings. The researcher acknowledged the ideas, thoughts, words and works of others (Leedy & Ormrod, 2001).

Finally, concerning the motivation of this study, it can also be argued that the investigation of NIHL and possible contributing factors were ethically driven. Interventions based on scientific evidence are intrinsically more respectful of the principle of autonomy because in the absence of such evidence there can be no valid statements of benefits and harms that underlie informed choice (Hyde, 2005). Ethically there is also an obligation to maximise overall beneficence (relates to doing good) and non- malfeasance (relates to the avoidance of doing harm), and it is widely believed that scientific evidence is a more valid approach to that end than practices based on clinical intuition (Hyde, 2005).

4.7. Sample

4.7.1. Population

The population refers to the all-inclusive data set about which the researcher wishes to draw a conclusion (Maxwell & Satake, 2006). A sample is a subset of a population ideally drawn in such a way to be representative of the larger population (Dane, 1990). Statistical methods then allow the researcher to make inferences about the characteristics of a population on the basis of information obtained from that specific sample (Maxwell & Satake, 2006). In this study the population and sample can be viewed in two different ways.

Firstly the total group of gold miners in South Africa can be considered as the population under investigation. The specific group of gold miners from which the audiogram and other information were used is viewed as a sample of the total population. This method of sampling used is called stratified sampling, where the population is divided into sub groups called strata, in this case the specific mines

(Maxwell & Satake, 2006). This sampling method assures that certain segments of the population are adequately represented in the sample.

Secondly the population under investigation can be seen as the gold mine workers at the specific mines involved in this study. The audiological, biographical and environmental information of 57 714 mine workers (AngloGold Ashanti, 2007) were included in this sample. The sample included all the gold miners employed at two gold mine groups, consisting of seven different gold mines. Audiogram data collected after 2001 of all mine employees were used, as it became obligatory to do a baseline hearing test after 2001 according to Instruction 171 (RSA Department of Labour, 2001). According to the Mine Health and Safety Act and the Occupational Hygiene Regulations the mine employers are obliged to monitor the mine workers' hearing when persons are subjected to an occupational health hazard, i.e. an equivalent exposure level exceeding the limit of 85dB TWA (Franz & Phillips, 2001). Every gold miner had at least a baseline audiogram and an annual audiogram. The initial data made available for use comprised of 232 458 audiograms (baseline test results and subsequent annual hearing screening results). After data cleaning (see section 4.9.2) 171 441 audiograms were available for analysis. These were further reduced to the most recent audiogram per worker. Workers of all ages, across all genders and cultural groups as well as different exposure groups, were included.

Workers included as participants were defined in terms of specific exposure levels based on the noise measurements done by the occupational hygienists of the specific mines. Within these noise-exposure categories specific variables were used to further define the participants, such as the occupation of the mine worker (e.g. rock driller). The audiological and other biographical data of the total population of the participating mines were used. Data received from the mines however, did not include information regarding certain characteristics (such as age or race) of all participants. Only results of participants with this information available were used. As a consequence the complete sample of certain groups (such as white males in Noise Group 1) could not be used and the group for which data was available was used. Because of the very large sample size of the cohort (from which these purposive samples were selected), numbers of participants with the relevant information were still sufficient to do statistical analyses and statistical significance could be obtained.

Finally matched sampling was also used to select the participants for the different Noise Groups in order to detect a statistical significance between the groups that can be attributed to the influence of the independent variable (noise) (Maxwell & Satake, 2006). Variables such as age at test, type of noise exposure and length of noise exposure between the audiograms were matched within these three groups.

4.7.2. Criteria for selection of participants

Participants were selected according to set criteria to increase internal validity and to control the effect of variables on the hearing of the gold miners. Selection criteria included exposure to hazardous occupational noise either underground, on surface or no known occupational noise exposure, the type of noise exposure (based on the homogenous exposure group), race and gender. Data were selected from audiometric and noise measurement records of the participants, made available by the mine’s occupational health department. Data categories in the original dataset included the following information: a company number, audiogram test dates, audiogram test times, type of audiogram, user code, thresholds for the air conduction frequencies at 0.5, 1, 2, 3, 4, 6, 8 kHz in both the left and right ear, schilling action and period, audiometer location, audiometer make, audiometer model, audiometer serial, audiometer calibration date, job description (company, responsibility, department, activity, section, designation, position), percentage binaural impairment (PBI), percentage monaural impairment left (PMIL), percentage monaural impairment right (PMIR), percentage loss of hearing (PLH), PLH shift, gender, race, initials, title, surname, company name, place name, ID number, passport number, passport country number, last referral date, last reported date, training date, last compensation date, date of birth. Not all these categories had data included for participants. The data that were used, either as it had been presented in the document or to deduce other information (such as age at test), were the following: a unique number per participant, audiogram test dates, type of audiogram, thresholds for the air-conduction frequencies at 0.5, 1, 2, 3, 4, 6, 8 kHz in both the left and right ear, job description, percentage loss of hearing (PLH), gender, race, ID number.

4.7.2.1. Noise exposure

Participants were selected according to their current exposure level to workplace noise. Exposure levels were described in terms of a specific occupation, as specific occupations are matched with different exposure levels, e.g. pneumatic rock drill equals ~108 dB (A) (Phillips, et al., 2007). The different exposure levels/occupations were then categorised in 4 groups namely: 1) above surface noise exposure (≥85 dB A), 2) below surface noise exposure (≥85 dB A), 3) no know occupational noise exposure and 4) uncertain levels of noise exposure e.g. students and trainees. Surface noise sources include conveyor belts, crushers and transportation equipment (Hessel & Sluis-Cremer, 1987). Underground sources of high noise levels include rockdrills, ventilation fans, transportation equipment and explosive blasts (Hessel & Sluis-Cremer, 1987). Blasting and drilling underground differ from that on the surface, being influenced by mine geometry, openings and friction from wall roughness. As with other impulsive exposures, the cumulative effect on mine workers is unclear (McBride, 2004). The levels of noise exposure were not documented in the audiogram data files. Based on dosimeter data received from the mine's noise hygienist (per occupation) the occupational groups were divided into different groups. Many of the occupations, however, had no noise data available and the classification of these occupations into the four Noise Groups was undertaken by the occupational medical examiner and the noise hygienist. Sub groups (e.g. Noise Groups 1) were compared to other sub groups (No Noise Group). In order to narrow the analysis down and to use a group with homogenous noise exposure (referred to as homogenous exposure groups (HEG) at the mine where participants work), two alternative sub groups were also analysed and compared within the three groups i.e. drillers (high levels of noise exposure) vs. administration workers (no known noise exposure).

Years of exposure were also taken into account by stratifying participants into different working year groups (based on the years of exposure to occupational noise). These working years were not available from the data set received from the mine. Combining different data sets, using individual employment numbers allocated to workers made it possible to calculate working years based on information about the date engaged (at work) and the date of the most recent audiogram. This data were not available for all participants and made stratification into working years possible for only a limited number of participants.

4.7.2.2. Age, race and gender

Because of the many similarities and interactions between NIHL and age-related hearing loss (ARHL) it is imperative to take into account the contribution of ARHL when determining the effect of noise on hearing (Ciletti & Flamme, 2008; Niskar, et al., 2001; Pyykkö, Toppila, Zou & Kentala, 2007; Dobie, 2001; Hoffman, Dobie, Ko & Themann, 2010; Flamme, et al., 2011). Participants were stratified into different age groups namely: 16 to 30 years, 31 to 40 years, 41 to 50 years, 51 to 60 years and 61 to 65 years. For sub aim 4 however, to assess the combined effect of various biographical, environmental and work-related variables on hearing status, data were compared to data from the available criteria standards (ISO, 1990; ANSI, 1996). In order to compare age groups participants were also classified in the age categories used by these standards namely 25 to 34 years, 35 to 44 years, 45 to 54 years and 55 to 64 years. Finally participants were classified according to their gender (male or female) and their race (black or white).

4.7.3. Description of research participants

The following tables and graphs serve to describe the research participants and their respective divisions into different groups and categories and the number of participants in each group.

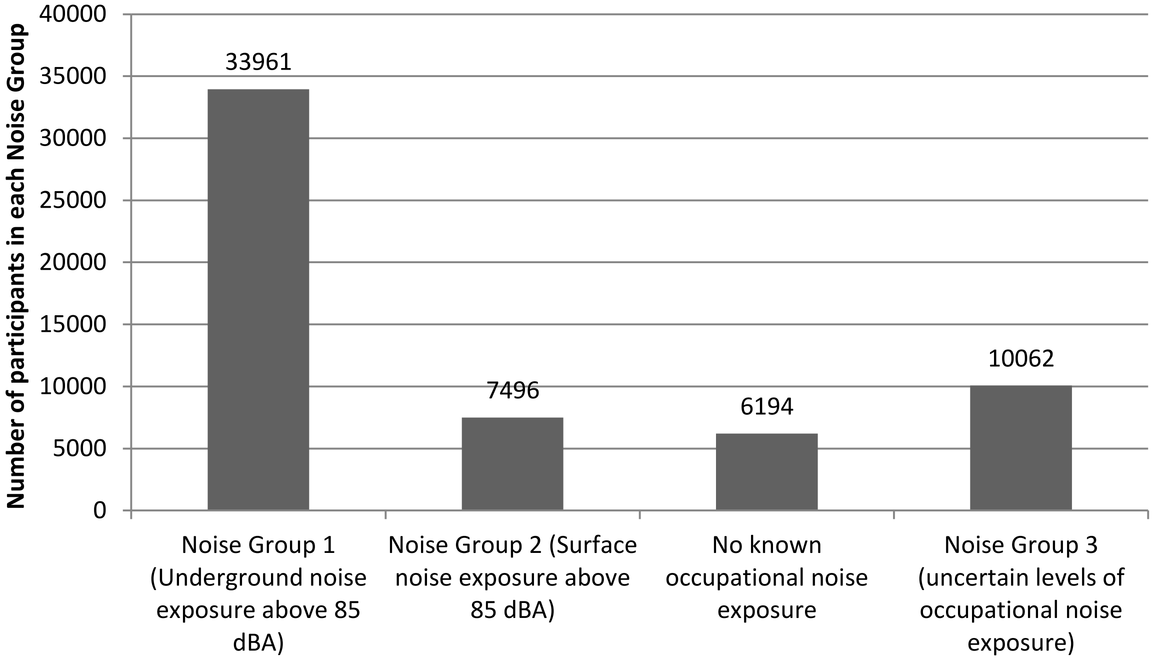


Figure 4-2 Number of participants categorised into the different Noise Groups $(\boldsymbol{N_{total} = N_{Noise\ Group\ 1} + N_{Noise\ Group\ 2} + N_{No\ Noise\ Group} + N_{Noise\ Group\ 3} = 57713})$

Figure 4.1 shows the numbers of participants in each Noise Group. Noise Group 1 (underground noise exposure ≥85 dB A) had the most participants, followed in numbers by Noise Group 3. Because the noise exposure of participants in this group was uncertain (either job descriptions were unclear, such as “trainee”/ “consultant”, or no data on noise exposure was available for the specific job description), analysis of the data for this Noise Group was not done.

Table 4-1 Number of participants for each occupation (labelled by the mine) constituting each Noise Group.

$$(N_{total} = N_{Noise\ Group\ 1} + N_{Noise\ Group\ 2} + N_{No\ Noise\ Group} + N_{Noise\ Group\ 3} = 57713\ )$$

Noise Group occupations	N	Noise Group occupations	N	Noise Group occupations	N	Noise Group occupations	N
Noise Group 1 (Underground noise exposure >85 dB A)	**33961**	**Noise Group 2 (Surface noise exposure >85 dB A)**	**7496**	**No Noise Group (No known noise exposure)**	**6194**	**Noise Group 3 (Unknown occupational noise exposure)**	**10062**
AQUAJET OPERATOR	61	ACCLIMATISATION	1	ACCOUNTS	117	WED	24
BACKFILL	5	BLACKSMITH	1	ADMIN	2211	AIR QUALITY ANALYST	4
BANKSMAN-	70	BUILDER	34	ANALYST	69	APTITUDE TESTING	1
BELL RINGER	1	BULLDOSER	1	BIOLOGICAL TESTING	6	ASSISTANT	5
BELTSMAN	26	CARPENTER	54	BUYER	2	BARRIER	3
BLASTER	1	CRANE DRIVER	18	CHANGE HOUSE	17	BATTERY	5
BOILERMAKER	926	CREW BOSS	6	CLAIMS	1	CABLE	1
BORE OPERATOR	1	CREW LEADER	19	CLEANER	1008	COMPRESSOR DRIVER	14
BOX CONTROLLER	76	DEVELOPER	19	COMMERCIAL	67	CONSTRUCTION	3475
CENTRIFUGE OPERATOR	106	DIESEL MECHANIC	22	COMMUNICATION	6	CONTRACTOR	149
CONVEYANCE OPERATOR	917	DRIVER HEAVY DUTY	402	COOK	628	CONTROL ROOM	13
CREW BOSS	21	DRIVER LIGHT	2	DESIGNER	22	CONTROLLER	77
CREW LEADER	1626	DRIVER TRAIN	1	DRIVER CAR	20	DOMAIN	48
CUTTER	2	ELECTRICIAN	76	ENVIRONMENTAL	43	DRAUGHTING	3
DEVELOPER	187	ENGINEERS	327	HOSTEL	26	DRAUGHTSPERSON	1
DIESEL MECHANIC	16	FITTER AND TURNER	103	INCAPACITATED	11	ENGINEER	5
DRILLER	4399	FOREMAN	85	INSPECTOR	4	ESTIMATOR	3
DRIVER TRAIN	3	FRIDGE PLANT	27	INSTRUCTOR	54	EVALUATION	4
ELECTRICIAN	666	GANG SUPERVISOR	4	INSTRUMENTS	6	EVALUATOR	13
ENGINEER	1815	GARDEN SURFACE	94	INVENTORY	5	FACILITATOR	1
ESH	2	GARDEN SURFACE LAWNMOWER	2	LAB	46	FIRE PATROLMAN	4
EXPLOSIVES	1	GROUTING	18	LAB TECHNICIAN	1	GEOLOGICAL	26
FITTER AND TURNER	818	LAUNDRY	3	LAMP REPAIRER	64	GEOLOGIST	13
FOREMAN	354	LEADER	2	LOGISTICS	20	GEOLOGY	4
GANG SUPERVISOR	12	LOADER	56	MANAGER	521	GLAZER	1
GRINDER OPERATOR	1	MACHINE	170	PAINTER	69	GOLD LOSS	5
GROUTING	111	MESH AND LACING	2	PANEL COORDINATOR	18	GRADE OFFICER	6
HOIST DRIVER	1	METALLURGY	5	PLANNING	1	GRADUATE	124
LEADER	20	MINE CAPTAIN	26	PROCESS LEADER	2	HANDYMAN	13
LOADER	399	MINER	423	PROCUREMENT	1	HELPER	5
LOCO DRIVER	1888	ONSETTER	18	PRODUCTION	3	HYDROLIC R/BREAK	1

Noise Group occupations	N	Noise Group occupations	N	Noise Group occupations	N	Noise Group occupations	N
Noise Group 1 (Underground noise exposure >85 dB A)	**33961**	**Noise Group 2 (Surface noise exposure >85 dB A)**	**7496**	**No Noise Group (No known noise exposure)**	**6194**	**Noise Group 3 (Unknown occupational noise exposure)**	**10062**
MACHINE	662	PIPES AND TRACKS	1	RADIATION	3	LABOURER	644
MESH AND LACING	5	PLANT ATTENDANT	183	RECREATION	1	LASHER	22
METALLURGY	7	PLANT CREW	16	RESOURCE MANAGER	9	LEARNER	18
MINE CAPTAIN	203	PLATE LAYER	1	SALES	1	MAINTENANCE	38
MINER	2730	PLATER AND WELDER	2	SALVAGE WORKER	7	MASON	11
MINER BLASTER	11	PLUMBER	18	SAMPLING	143	MATERIALS	1
MONO WINCH DRIVER	4	PUMP ATTENDANT	17	SANITATION CREW	48	MECHANIC	44
ON SETTER	251	RAISE BORE OPERATOR	1	STAGE HAND	5	MEDICAL	731
PIPES AND TRACKS	15	REFRIGERATION PLANT	32	STORE	172	MESSENGER	1
PLANT ATTENDANT	161	RIGGER	14	STRATA CONTROL	4	NOZZLE OPERATOR	2
PLANT CREW	16	SCALAR OPERATOR	1	STUDENT	1	OFFICER	1
PLATE LAYER	1	SCRAPER WINCH OPERATOR	403	SWEEPER	2	OPERATOR	278
PLATE LAYER UNDERGROUND	1	SHIFT BOSS	26	SWITCHBOARD OPERATOR	1	PORTER	19
PLUMBER	7	SLIMES	6	SYSTEMS CONTROLLER	12	PUNCH OPERATOR	5
PRINTING PRESS OPERATOR	1	STEEL FIXER	11	TIMEKEEPER	5	QUALITY CONTROL	2
PUMP ATTENDANT	1	STEEL RECONDITIONER SURFACE	19	TRAINING	615	RAIL TRACKS	5
PUMP ATTENDANT	212	SUPPORT	5	TRANSPORT	93	RECEIVER	3
RAISE BORE OPERATOR	18	SURFACE	2688	WAREHOUSING	3	REDUCTION	13
REFRIDGERATION PLANT	13	SURFACE DRILLER	3				
RIGGER	121	SURVEY	1				
RUBBER LINING	1	TEAM LEADER, SURFACE	601				
SCALAR OPERATOR	1	TEAM MEMBER, SURFACE	51				
SCOTT WINCH DRIVER	1	TIMBERING	159				
SCRAPER	1000	WASTE DISPOSAL	1				
WINCH OPERATOR	222	WELDER	208				
SHIFT BOSS	1304	WINCH DRIVER	28				
SHOTCRETTING	76	WINDING ENGINE DRIVER	566				
SHUTTERHAND	5	WIRE MESHER	76				
SINKER	17	YARDMAN	11				
STEEL FIXER	2						
STEELRECONDITIONER UNDERGROUND	16						

Noise Group occupations	**N**	**Noise Group occupations**	**N**	**Noise Group occupations**	**N**	**Noise Group occupations**	**N**
Noise Group 1 (Underground noise exposure >85 dB A)	**33961**	**Noise Group 2 (Surface noise exposure >85 dB A)**	**7496**	**No Noise Group (No known noise exposure)**	**6194**	**Noise Group 3 (Unknown occupational noise exposure)**	**10062**
STOPE	4323						
STOPE DRILLER	6						
STOPE LASHER	3						
SUPPORT	35						
SURVEY	5						
TEAM LEADER	1462						
TEAM MEMBER	109						
TIMBERING	97						
UNDERGROUND	1081						
UNDERGROUND ASSISTANT	820						
UNDERGROUND BANKSMAN	46						
UNDERGROUND ELECTRICIAN	11						
UNDERGROUND HANDYMAN	1						
UP GRADER	4						
VAMPING	80						
VENTILATION	42						
VOID FILLING	12						
WATER JET OPERATOR	321						
WINCH	1082						
WINCH DRIVER	261						
WINCH OPERATOR	2554						
WINCH TRANSPORTER	2						

Table 4.1 shows that 234 unique occupations were labelled by the mine and allocated to participants in the audiogram data set. Most of these occupations are done underground and workers are exposed to ≥ 85 dB A occupational noise.

In order to aid comparison between different noise-exposed groups two sub groups from Noise Group 1 and the No Noise Group were also selected for comparison. These are the drillers and the administration personal (marked in grey in table 4.1). Based on data received from the mine’s noise hygienist (personal dosimeter measurements) drillers in these specific mines are exposed on average to 140 dB A noise (minimum 129.4 dB A and maximum 158.5 dB A). Participants doing administration work are not exposed to any known occupational noise. The numbers of participants in these two HEGs were 2 211 participants in the Administration Group and 4 399 participants in the Driller Group.

Table 4.2 shows the breakdown of participants in the different Noise Groups into different age categories as described in section 4.4.2.2.

Table 4-2 Number of participants categorised into different age categories per Noise Group (Total N=57713)

Age categories	**Number of participants**	**Age categories**	**Number of participants**
Noise Group 1 (Underground noise exposure >85 dB A)	**Total N=33961**	**No Noise Group (No known noise exposure)**	**Total N=6194**
16 to 30yrs	7568	16 to 30yrs	1623
31 to 40yrs	11190	31 to 40yrs	2327
41 to 50yrs	11058	41 to 50yrs	1696
51 to 60yrs	3683	51 to 60yrs	492
61 to 65yrs	250	61 to 65yrs	24
Age categories	**Number of participants**	**Age categories**	**Number of participants**
Noise Group 2 (Surface noise exposure >85 dB A	**Total N= 7496**	**Noise Group 3 (Unknown occupational noise exposure)**	**Total N=10062**
31 to 40yrs	2257	31 to 40yrs	2261
16 to 30yrs	1824	16 to 30yrs	2839
41 to 50yrs	2245	41 to 50yrs	2712
51 to 60yrs	1047	51 to 60yrs	2035
61 to 65yrs	83	61 to 65yrs	141

For the HEGs, driller and administration, the number of participants per age group is shown in figure 4.2 below.

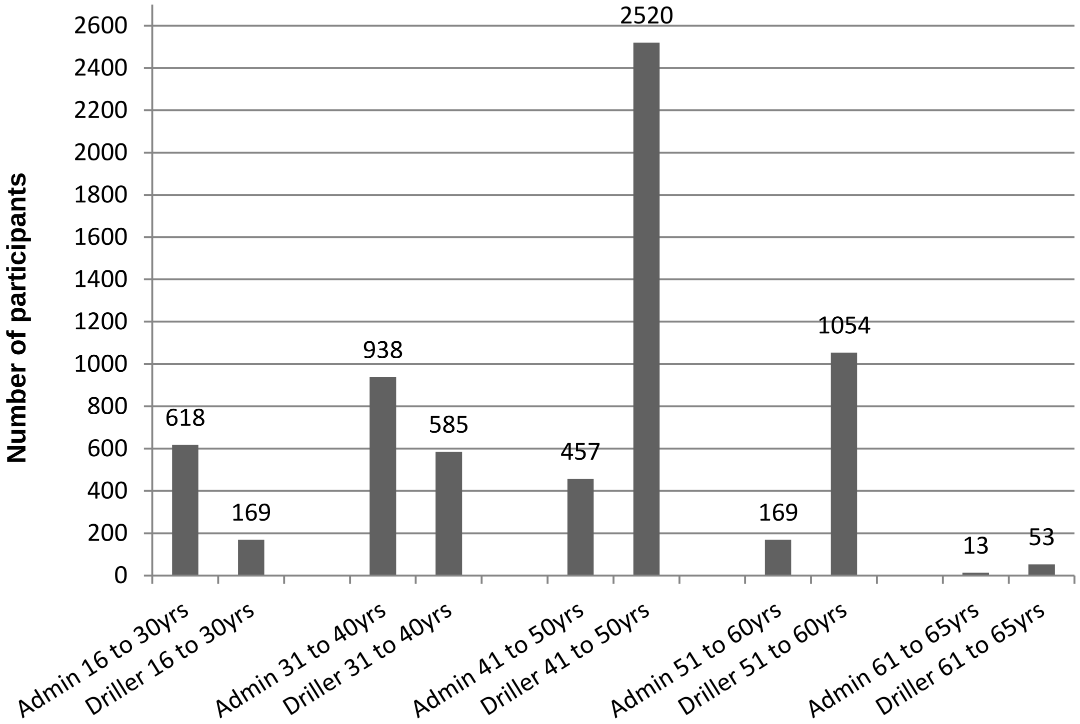


Figure 4-3 Number of participants in each age category for the Driller and Administration groups ($N_{Admin} = 2211$; $N_{Driller} = 4399$)

Participants were further divided into different gender and race groups. Information on the gender and race of participants were not available for all participants and the addition of numbers for the different categories do not amount to the total number of participants.

Table 4-3 Number of participants categorised into different age categories and race groups (white and black) per Noise Group

Noise Groups/ Age categories/ Black (B)/ White (W)	**Number of participants**	**Noise Groups/ Age categories/ Black (B)/ White (W)**	**Number of participants**
Noise Group 1 (Underground noise exposure >85 dB A)	$N_{Noise\ Group\ 1}$ **=33961**	**No Noise Group (No known noise exposure)**	$N_{No\ Noise\ Group}$ **=619**
16 to 30yrs	$N_{16-30yrs}$ **=7568**	**16 to 30yrs**	$N_{16-30yrs}$ **=1623**
B	6192	B	1301
W	1340	W	303
31 to 40yrs	$N_{31-40yrs}$ **=11190**	**31 to 40yrs**	$N_{31-40yrs}$ **=2327**
B	9739	B	1937
W	1361	W	363
41 to 50yrs	$N_{41-50yrs}$ **=11058**	**41 to 50yrs**	$N_{41-50yrs}$ **=1696**
B	9570	B	1405
W	1410	W	267
51 to 60yrs	$N_{51-60yrs}$ **=3683**	**51 to 60yrs**	$N_{51-60yrs}$ **=492**
B	2902	B	377
W	754	W	104
61 to 65yrs	$N_{61-65yrs}$ **=250**	**61 to 65yrs**	$N_{61-65yrs}$ **=24**
B	154	B	11
W	94	W	12
Noise Group 2 (Surface noise exposure >85 dB A)	$N_{Noise\ Group\ 2}$ **=7496**	**Noise Group 3 (Unknown occupational noise exposure)**	$N_{Noise\ Group\ 4}$ **=10062**
16 to 30yrs	$N_{16-30yrs}$ **=1824**	**16 to 30yrs**	$N_{16-30yrs}$ **=2839**
B	1485	B	2339
W	316	W	470
31 to 40yrs	$N_{31-40yrs}$ **=2257**	**31 to 40yrs**	$N_{31-40yrs}$ **=2261**
B	1873	B	1955
W	345	W	286
41 to 50yrs	$N_{41-50yrs}$ **=2245**	**41 to 50yrs**	$N_{41-50yrs}$ **=2712**
B	1849	B	2431
W	375	W	262
51 to 60yrs	$N_{51-60yrs}$ **=1047**	**51 to 60yrs**	$N_{51-60yrs}$ **=2035**
B	777	B	1849
W	259	W	174
61 to 65yrs	$N_{61-65yrs}$ **=83**	**61 to 65yrs**	$N_{61-65yrs}$ **=141**
B	59	B	114
W	24	W	27

In table 4.4 the number of participants per race group for the Driller and Administration groups is shown.

Table 4-4 Number of participants in the Driller and Administration Groups in the different race groups (black and white)

DRILLER	$N_{Driller} = 4399$	**ADMIN**	$N_{Admin} = 2211$
B	4096	B	1885
W	287	W	293

Table 4.5 shows the number of participants per Noise Groups in the different race (white and black) and gender groups. As noted earlier, information on the gender and race of participants was not available for all participants and the addition of numbers for the different categories does not amount to the total number of participants.

Table 4-5 Number of participants in each Noise Group, categorised by race and gender

Noise Group/ Race group (black/ white)/ Gender (female/male)	**Number of participants**	**Noise Group/ Race group (black/ white)/ Gender (female/male)**	**Number of participants**
Noise Group 1 (Underground noise exposure >85 dB A)	$N_{Noise\ Group\ 1} =$ **33961**	**No Noise Group (No known noise exposure)**	$N_{No\ Noise\ Group} =$ **6194**
Black	**28724**	**Black**	**5053**
Female	849	Female	314
Male	17933	Male	2790
White	**4987**	**White**	**1056**
Female	217	Female	42
Male	2687	Male	508
Noise Group 2 (Surface noise exposure >85 dB A)	$N_{Noise\ Group\ 2} =$ **7496**	**Noise Group 3 (Unknown occupational noise exposure)**	$N_{Noise\ Group\ 4} =$ **10062**
Black	**6064**	**Black**	**8735**
Female	398	Female	459
Male	4388	Male	5876
White	**1336**	**White**	**1239**
Female	211	Female	157
Male	783	Male	688

4.8. Data Collection

4.8.1. Collection protocols and procedures

In terms of the Mine Health and Safety Act (Department of Minerals and Energy, 1996), Instruction 171 (COIDA, 2001) and South Africa National Standards (SANS10083:2007, 2007) the employer is obliged to establish and maintain a system of medical surveillance for all employees in any working place where the equivalent, continuous A-weighted sound pressure level, normalised to an 8 hour working day or a 40 hour working week exceeds 85 dB (A). Legislation (Instruction 171) made it compulsory that a baseline audiogram is conducted for all individuals within two years after this legislation had been published and within 30 days for new employees who had not worked previously. The mine concerned in this study complied with these regulations and therefore audiograms from the year 2001 onwards until 2008 were used.

Data consist of hearing tests (audiograms) of the gold miners at the three different mines (Tautona, Savuka and Mponeng) at AngloGold Ashanti. The occupational medical/health department accessed the mine’s electronic database and exported all required information to Microsoft Excel 2007 worksheets. The audiometric records consisted of pure-tone air-conduction audiograms for right and left ear respectively. Some audiograms were obtained from a diagnostic evaluation, other from a baseline, periodic screening, monitoring or exit assessment. These audiograms have been obtained at the mines involved in this study by mining personnel and comprise the following frequencies: 0.5, 1, 2, 3, 4, 6 and 8 kHz. Another set of data that was used for this study is the percentage loss of hearing (PLH). This value was extracted from the mine’s audiometric database and is calculated for each set of audiometric data. The PLH forms the principal criterion for assessing hearing status for compensation claims. Shifts in PLH are identified by comparing current values with that from the baseline audiogram (for cumulative shifts) or previous audiograms (for interim shifts) (COIDA, 2001). PLH is derived from combining the individual’s hearing threshold levels at 0,5; 1; 2; 3 and 4 kHz, using tables from Instruction 171 (COIDA, 2001). A shift of ten per cent or more in PLH, as compared with the baseline audiogram, has been accepted as the level at which a compensation claim may exist (COIDA, 2001). In all cases where PLH values exceeded 10% diagnostic hearing test results were available. Where PLH values were below 10% baseline testing or screening results were used (see table 4-6 below for description). The following information was also gathered from the available database: Age of the miners, occupation (was classified according to the noise-exposure level), years of service in the different working environments, race and gender.

Audiometry for this study was conducted in a soundproof room that complied with the relevant requirements for background noise and environmental conditions stipulated in the South African National Standards (SANS) document (SANS10154-1:2004, 2004; SANS10154-2:2004, 2004). This standard provides background noise limits for air-conduction, bone-conduction and sound-field audiometry. Audiometry was conducted at the specific mines according to the specifications set out in Instruction 171 (RSA, Department of Labour, 2001).

The following table from the handbook of occupational health practice in the South African mining industry (Franz & Phillips, 2001) summarises the application, purpose and procedural requirements for audiometric testing of mine workers. These requirements were adhered to by mining personnel when audiogram data for the study were collected.

Table 4-6 Definition and requirements for audiometry as required by the gold mines under investigation, its application, purpose and procedural requirements (Franz & Phillips, 2001)

Type of audiometry	Application	Purpose	Procedural requirements
Baseline (Code 3)	Before allocation to work in a noise zone (TWA ≥85 dB A) or 30 days of commencing such work	To provide a reference for evaluating any future changes in hearing status	Before testing, a 16-h period with no exposure to noise ≥85 dB A (use of HPDs complying with SANS 10083:2007, II or III is NOT acceptable); use better of the two audiograms that are within 10 dB at 0,5; 1; 2; 3 and 4 kHz; where consistency is not possible or pathology is suspected, refer for medical opinion to consider possible audiologist or specialist evaluation; incorporate results into medical surveillance records.

Type of audiometry	Application	Purpose	Procedural requirements
Periodic screening **(Code 1)**	Annually for noise-exposed individuals (TWA ≥85 dB A)	To quantify any permanent hearing loss that results from exposure to noise	Before testing, a 16-h period with no exposure to noise, ≥85 dB A (use of HPDs complying with SANS 10083:2004, II or III is acceptable); incorporate results into medical surveillance records
Monitoring **(Code 2)**	6-Monthly for high-risk exposure (TWA ≥105 dB A), participant to employer's code of practice	To identify temporary threshold shifts and enable the prevention of permanent hearing loss; to evaluate the efficacy of HPDs	Conduct testing as soon as possible after exposure to noise, i.e. at the end of the working shift
Exit **(Code 6)**	On conclusion of employment in a noise zone (TWA ≥85 dB A) or on employee's termination	To provide a record of hearing levels on conclusion of employment in a noise zone	Before testing, a 16-h period with no exposure to noise, ≥85 dB A (use of HPDs complying with SANS 10083:2004, II or III is acceptable); incorporate results into medical surveillance records
Diagnostic **(Code 5)** **Compensation** **(Code 4)**	When medical opinion recommends a specialist evaluation for purpose of investigating ear pathology, inconsistent baseline results or a potential compensation claim for NIHL	To enable a specialist evaluation of hearing status as required; to support a possible compensation claim, where indicated	Before testing, a 16-h period with no exposure to noise ≥85 dB A (use of HPDs complying with SANS 10083:2004-I, II or III is NOT acceptable); to determine eligibility for compensation, two audiograms must be recorded during two different sittings (both may be on the same day). If the two differ by more than 10 dB for either ear at any mandatory test frequency (0,5; 1; 2; 3; 4; 6 or 8 kHz), a third audiogram must be recorded during a third sitting. Where the third audiogram also indicates inconsistencies >10 dB, participant should be re-evaluated in six months' time. Thereafter, if inconsistent results are still not obtainable, participant may be referred for further specialist evaluation of hearing loss; incorporate results into medical surveillance records

(Source: Handbook of Occupational Health Practice in the South African Mining Industry (Franz & Phillips, 2001))

4.8.2. Personnel requirements for data collection

The baseline, periodic screening, monitoring and exit audiograms were conducted by personnel (audiometrists, occupational medical personnel, audiologists and medical practitioners specialising in otorhinolaryngology) who had been registered with the Health Professions Council of South Africa whereas the diagnostic audiometry was conducted by audiologists and medical practitioners specialised in otorhinolaryngology registered with the Health Professions Council of South Africa (Franz & Phillips, 2001).

4.8.3. Requirements of the equipment and test procedures for data collection

The audiometer used in the screening set-up at the occupational health facility of West Wits is the Tremetrics RA 600 Type 4 audiometer (serial no 971499) with TDH 39 headphones. Up to ten workers can be tested simultaneously using the audiometer’s automatic testing procedure and specifically designed software (Everest). This allows for automatic and simultaneous testing of more than one client at a time, as well as saving the information to a database. Diagnostic testing is conducted in another facility by using the GSI 61 audiometer (serial no AA041138).

Acoustic enclosures or soundproof rooms for audiometric testing comply with the requirements for background noise and environmental conditions specified in SANS 10083:2007.

The following audiometer calibration and verification requirements were met (Guild et al. 2001):

- Screening and diagnostic audiometers had valid calibration certificates at the time of the commissioning of this study (see Appendix D – calibration certificate).
- Calibration service providers had the necessary training and equipment, and demonstrate traceability to the National Acoustic Standard. Calibration is annually done by ACTS, Audiometric Calibration and Training Services.

- Personnel conducting audiometry validated the accuracy and calibration continuity of audiometers on a weekly basis by means of subjective or biological calibration checks. These records are retained for record-keeping.
- Each day, prior to testing, the personnel conducting audiometry confirmed the correct functioning of the audiometer, inspected all cables and connections, confirmed the proper functioning of the patient's response button, and performed a listening check to ensure the absence of unwanted sounds.

Audiometric testing procedures included clear instructions prior to testing and a familiarisation phase to confirm participant competence by observing responses to preliminary test signals (Franz & Phillips, 2001). This is followed by the test phase during which hearing threshold levels are measured and recorded. The ascending test method (according to ISO 6189) is recommended (Franz & Phillips, 2001).

4.9. Data analysis procedure

In this retrospective study, relevant data were extracted from the gold mine's database (Everest) and imported to a software programme (Microsoft Excel 2007 and 2010) to aid analysis of the data.

4.9.1. Data organisation

The following information was gathered from the available database: Age of the miners, occupation (classified according to the noise-exposure level), years of service in the different working environments and gender. Audiometric data were organised using the audiometric frequencies tested (thus decibel (dB) hearing- level (HL) threshold values per frequency) per ear, binaural averages and the PLH values. Data were transferred to a Microsoft 2007 and 2010 Excel worksheet format from where it was transferred to a statistical analysis programme.

In order to answer the aims set out as research aims one to four, audiogram data were used. The Everest data set had limited data available on the employee's gender, race and engage date (date that work commenced). Thus another information data set was used and combined by using each participant's unique employee numbers. In order to aid comparison each participant was then awarded a new number in numerical order. This data used involved a dB HL value at each frequency (0,5; 1; 2; 3; 4; and 6/8 kHz) for each participant for the left and right ears. Using these values (in dB HL) a high frequency average (HFA) for frequencies 3,4 and 6 kHz for each ear were calculated and also a binaural average HFA (HFA346). The same was done with the low frequency average (0.5, 1, 2 kHz). Each participant had a LFA512 binaural and for the left and right ears. The reason for analysing the lower and higher frequencies separately was to be able to make a more specific comparison between the low and high frequencies, due to the fact that noise and age have a greater influence on the higher frequencies (Sliwinska-Kowalska et al., 2006), while for example the PLH's weighing is highest for hearing loss at 1 kHz and lowest for hearing loss at 4 kHz (Guild et al., 2001). Another reason for choosing this specific high frequency category is that Girard et al. (2009) reported that the severity of hearing impairment at 3, 4 and 6 kHz (average bilateral hearing-threshold levels exceeding a 15 dB of hearing loss), is increasing the risk for work-related accidents. Hearing loss categories were also calculated using the available thresholds data and this was organised in the hearing categories proposed by Yantis (Yantis, 1994). The following table summarises these hearing loss categories:

Table 4-7 Hearing threshold categories based on the degree of impairment proposed by Yantis (1994) and used by Picard (2008) and Girard (2009)

Category of hearing sensitivity	Per frequency Per hearing threshold average for high frequencies (3, 4, 6 kHz) (HFA346) Per hearing threshold average for low frequencies (0.5, 1 and 2 kHz)(LFA312)
Normal hearing	0-15 dB
Just noticeable hearing loss	16 to 30 dB
Mild hearing loss	31 to 40 dB
Moderate hearing loss	41 to 50 dB
Severe hearing loss	≥51 dB

From table 4.7 it is clear that these hearing loss categories are conservative compared to other criteria (Jerger, 2009). Based on the data from a large scale study

(N=53000) (Picard, et al., 2008), Picard (2012) suggests that within the context of NIHL, Yantis' low fence at 16 dB HL appears to be a sensible cut-off point to decide on the presence of some minimal degree of hearing loss. Furthermore, the distribution of their data showed only a few outliers beyond the 60 dB HL mark. As a whole, their data indicate that the Yantis classification may be a finer grain scale to represent NIHL (Picard, 2012).

In order to reach the aims set out as research aims, values that were used for statistical analyses also included the PLH (as calculated through the use of the calculation tables of Instruction 171), as well as other calculations used to determine hearing impairment such as the method of the AMA (Dobie, 2001). PLH values were used to divide participants into different PLH categories. The AMA values were calculated based on the AMA formulae (AMA, 2001), using an average of thresholds at 0.5, 1, 2 and 3 kHz in both ears, subtracting the low fence of 25dB from the average, and multiplying the value with 1,5%. The value of the best ear is then multiplied by five and the value of the worst ear is added to that, the total divided by 6 (better ear weighted 5:1) to supply the AMA percentage hearing impairment. A best and worst ear AMA were calculated and used to calculate an AMA hearing impairment percentage. Using the date of the most recent audiogram and the “engage date” to indicate date of employment (as used by the mine) working years were calculated. Unfortunately this information was not available for all participants and analyses were only done were this calculation was possible. Using the date of the most recent audiogram and the date of birth, an age at test was calculated. Different categories for ages as well as working years were calculated using these dates.

4.9.2. Data cleaning

Data were cleaned by identifying and correcting erroneous codes (Dane, 1990). When data were transferred from the Everest software programme to Microsoft Excel 2007/2010, several instances of incorrect numbering, unreliable data and more were evident, for instance, many participants and three or even more audiograms per year. These audiograms as well as audiograms with errors were deleted from the data set. The original amount of Microsoft Excel 2007 rows/ audiogram records was

22 3873. After data cleaning 171441 Microsoft Excel data rows (audiogram records) were available for use. (A total of 52 432 rows were deleted).

The following table summarises these errors and the cleaning of the data.

Table 4-8 Summary of data cleaning done, reasoning and amount of audiogram data disregarded (Data cleaning reduced dataset from 223 873 records to 171 441 records)

Disregarded audiogram records	**Reason for deletion**	**Amount**
All duplicates were removed (Same worker, same day, same time, same audiogram)	Redundant	3 855 records deleted
All rows where an audiogram error code was recorded in threshold value cells between 500-4000Hz were deleted.	Values in these frequencies are important for calculations of hearing impairment	640 records deleted
All rows where No Response (NR) values were recorded in more than 4 frequencies in one ear. Where a diagnostic test (5) for these workers was available, the results of the diagnostic test were kept in the file.	Values in these frequencies are important for calculations of hearing impairment. No hearing impairment calculations (Instruction 171) are possible without values at these frequencies. According to the Occupational Medical doctor mostly NR values are given when a worker did not participate or results were inconsistent.	150 records deleted
Where NR (no response) values were recorded for one or two frequencies (mostly high frequencies), and where results correlated with previous audiogram results (within 10dB's) maximum values (100dB) were given.	The mine audiometre has a maximum value of 99dB. If no value is given to these NRs, the calculations would be invalid. A 100dB value makes the researcher's change apparent and reflects the hearing loss without affecting the calculation significantly.	976 records deleted
No date of birth, thus no age groups		331 records deleted
All rows where one ear had normal threshold values and the other NR values	These results indicate a unilateral functional hearing loss (malingering). Interaural attenuation makes this scenario impossible	33 records deleted

Disregarded audiogram records	Reason for deletion	Amount
All audiograms marked as type2 (monitor) were changed to screen	This code was used very infrequently and no differences in pattern of use could be distinguished between the use of the screening code (1) and code (2).	
All rows where 2 or more tests were done on the same day were reduced in the following manner: • If a baseline (3) and baseline check (7) were similar the check (7) was deleted; • If two audiograms done on the same day were similar but a third not, the third was deleted; • If a screen(1) was followed by a diagnostic test(5) on the same day, the screen was deleted; • A test done for compensation (code 4) was kept if more than one test for the day was available; • If a diagnostic (5) or baseline audiogram (3) or screen (1) was repeated, the second test was kept (if it was similar to the first (+/- 5dB); • Tests done more frequently than once a year were not kept; • Exit tests (6) were done very often on the same day as a screening test (1). Only one test was kept and a code 6 was regarded as the same as a screening test (1).	Most baseline tests (3) followed on a baseline check (7). Baseline tests were done after the check and are more reliable. If more than one test of the same worker done on the same day were used, more weighting would be given to that audiogram. Diagnostic tests are more reliable than screening tests Test done for compensation is regarded as the final diagnosis	46 447 rows were deleted

4.9.3. Statistical analyses

After data-cleaning the data were analysed in collaboration with an experienced biostatistician from the Medical Research Council (Professor Piet Becker) according to a statistical analysis system (StataCoro. 2007. Stata Statistical Software: Release 10. College Station, TX: StataCorp LP). Both descriptive and inferential statistics were employed. Descriptive statistics served to organise and summarise this particular set of observations in a manner convenient for numerically evaluating the attributes of the available data (Maxwell & Satake, 2006). Tables and line graphs were primarily used to provide a visual and readily interpretable summary of the data. Measures of central tendency (means) and measures of variability (standard deviations, confidence intervals) were used. As threshold distributions of population-based samples (unlike distributions of multiple estimates for an individual) are usually positively skewed (ANSI, 1996), showing greater mean values compared to median values, the audiometric threshold distributions of the HFA346 and the LFA512 results (with the HFA346 indicative of noise-induced hearing loss (NIHL)) as well as per frequency analyses were analysed by their medians (50th percentile) and 95th percentiles. Medians for this study were calculated by the conventional method, where for example the the median of a group of 15 would be simply the 8th-ranked value. Another method used by some of the population standards (ISO 1990:1999), used for comparisons with this study's medians, calculated the median for grouped data, assuming that the cases in each 5-dB interval are evenly distributed (Dobie, 2006).

Inferential statistics allowed the researcher to generalise findings from the study sample to a similar group (population) from which the sample was drawn (Maxwell & Satake, 2006). To avoid any confounding influence of age in comparisons, 'age at test' was adjusted for during analyses using ANCOVA. This analysis of covariance (ANCOVA) is a procedure for comparing mean values of research variables while controlling for the influence of a continuous variable (covariate) such as age. A subset analysis was conducted on two homogenous noise-exposure groups, i) drillers (with known high levels of noise exposure) and the administrative personnel (with no known occupational noise exposure). Noise-concentration files received from the mine's occupational hygienist showed that drillers are exposed to drilling noise with an average of 140,85 dB (A), a minimum exposure level of 129,4 dB (A) and

Analysis of covariance (ANCOVA) and pairwise comparisons were used to establish whether statistically significant relationships existed between variables. To detect specific differences when groups were found to be significantly different ($p<0.05$) in the ANCOVA, pairwise comparisons between groups were done according to Fisher's Least Squares Differences Approach (F test). Given a null hypothesis and a significance level, the corresponding F test rejects the null hypotheses if the value of the F statistic is large (Le Prell, et al., 2007). The *p* value is understood as the probability that a null hypothesis were true. T-Tests, to determine significant differences between the mean scores of two groups, were also used to determine p-values. If the *p* value is smaller than a predetermined alpha level (0,05 for this study) it can be considered statistically significant, and the null hypothesis is rejected and the alternative hypothesis accepted (Brewer & Stockton, 2010). It is important to note that although some observed differences were statistically significant, the may not be clinically relevant. These statistical differences were mainly attributed to the very large sample size resulting in very small standard errors, where $t = \frac{x1-x2}{\sqrt{\frac{SD1}{n1}+\frac{SD2}{n2}}}$. (Large t-values result in very small p-values).

4.10. Validity and reliability

Underpinning the research endeavours is the question of credibility. The researcher needs to ensure that the conclusions are reliable and valid. In general, the validity of a measurement instrument is the extent to which the instrument measures what it is supposed to measure (Leedy, 2001). By controlling the threats to validity the investigator can eliminate many variables that could influence the results of the study (DeForge, 2010). Threats are often referred to as alternative explanations.

Four main sources of threats have been identified: internal, statistical conclusion, construct and external (DeForge, 2010). The internal validity of the research project as a whole has to do with its accuracy, meaningfulness and credibility (Dane, 1990). Internal validity focuses on what occurred during the implementation of the study that could influence the relationship between the independent and dependent variables (DeForge, 2010). The audiometric data that were used for analysis were collected using standards that are accepted worldwide as valid and reliable measures of hearing (SANS10083:2004, 2004). The PLH that was used is calculated using methods that are enforced by the Mine and Health Safety Act of South Africa (RSA, Department of Labour, 2001). Threats to the internal validity include the lack of information on recreational noise exposure of the participants. Recreational activities with excessively loud sound levels are an increasingly important factor to consider when investigating total noise exposure in workers (Neitzel, Seixas, Goldman, & Daniell, 2004). At football games for instance (a very popular recreational activity in South Africa) it has been shown that a real risk of noise-induced hearing loss is present because of the high levels of noise emitted by the vuvuzela (a horn-like instrument used during these games) (Swanepoel & Hall, 2010). Other threats include the lack of a working history for most workers and the use of screening audiograms where diagnostic data were not available. To control for these threats diagnostic hearing tests were uses whenever possible and audiogram data, obtained from diagnostic tests, were used in all cases where hearing loss deteriorated more than 10% between the baseline and subsequent hearing tests.

Validity also relies on the validity of the statistical conclusion. This involves the inferences about the correlation or co-variation between independent and dependent variables (DeForge, 2010). The statistician involved in this project has been involved in numerous human research studies at the Medical Research Council, acts as the principal statistician at the MRC, and provided guidance and mentoring to ensure that statistical analysis was conducted accurately.

The study's external validity is dependent on the representativeness of the sample (Leedy, 2001). Where the population is viewed as all gold miners in South Africa the large group of participants that participated in this study increased the representativeness of the sample. Generally it can be said that the larger the sample used in an investigation, the more accurate the estimate of the standard error was (Maxwell & Satake, 2006). Based on 2007 statistics (AngloGold Ashanti, 2007; Mwape et al., 2007) a sample of 30 650 gold miners represented 19,15% of the total gold miners' population (159 984). According to Gay (1995, as cited in Maxwell & Satake, 2006) 10-20 % of the population should be sampled for descriptive purposes and at least 30 participants are required for correlational studies. It is clear that the sample represents a sufficiently large proportion of the population of South African gold miners. The external validity is limited to the gold mining industry as other characteristics such as migrant living conditions and exposure to external agents, such as silica dust, that is used in the mining process for example, are specific to this population. As the entire population of the seven specific gold mines partaking in this investigation is included conclusions reached reliably represent these specific mines.

4.11. Chapter summary

In this chapter the research design and methodology were explained. The research question, aims and hypotheses were offered and explained. The methodology followed for the empirical part of the study was also presented with specific account of the data organisation (collection, cleaning and organisation), participant criteria, descriptive statistics, as well as the inferential statistics applied to investigate and describe the research constructs.

Chapter 5 subsequently presents all the findings obtained by applying the research methodology as explained in Chapter 4.