NOISE-INDUCED HEARING LOSS IN A PAPER MILL IN KZN SOUTH AFRICA

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Masters of Public Health in Occupational Hygiene

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DECLARATION

I, Christina Adriana Viljoen declare that this research report is my own work. It is being submitted for the degree of Masters in Public Health in Occupational Hygiene in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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ABSTRACT

It is well documented that repetitive exposures to high intensity sound can cause acoustic trauma to the ear resulting in hearing loss, and that occupational noise is a significant cause of adult-onset hearing loss. Research world wide has indicated a significant number of workers with hearing loss attributed to noise exposure. Noise-Induced Hearing Loss (NIHL) claims are responsible for the majority of occupational disease payouts.

The study was undertaken in order to determine the extent of hearing loss due to noise exposure that could be ascribed to excessive exposure to noise, and to describe the noise-induced hearing loss by severity, type of work, and area of work and duration of service.

The cross-sectional study included 466 workers employed in a pulp and paper mill in KwaZulu Natal (KZN) South Africa. It involved the assessment of 932 individual audiograms to diagnose noise-induced hearing loss and the calculation of the percentage loss of hearing from pre placement to the year 2005.

Audiometry results were presented for noise-induced hearing loss in relation to area of work, duration of service, categories of severity and age group.

The prevalence of noise-induced hearing loss in the pulp and paper mill was 21% (98/466) and with 79% (368/466) of workers whose audiograms returned results not indicating NIHL. 75 workers were excluded due to workplace transfers.

Type of work, area of work and years of service correlated significantly with a diagnosis of noise-induced hearing loss. As a department, the wood yard (which included the wood chipping facility, maintenance workers and workers with 10 – 20 years of service) showed the most significant association. In

categories of severity 16.7% of workers suffering from NIHL fall in the ≤ 5 Percentage Loss of Hearing PLH category.

This study has confirmed the findings of others that noise exposure is a significant hazard in industry and an effective noise control programme is the only way to reduce the risk of NIHL.

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NOMENCLATURE

- Noise-induced Hearing Loss (NIHL)
- Percentage Loss of Hearing (PLH)
- Hearing protective device (HPD)
- Compensation of Occupational Diseases and Injuries (COID)
- Decibel (dB)
- The National Institute for Occupational Safety and Health (NIOSH)
- South African National standard (SANS)
- Statistical package for social sciences (SPSS)
- American National Standard Institute (ANSI)
- Noise Reduction Ratio (NRR)
- Human Resources Management System (HRMS)
- Equivalent continuous A-weighted sound pressure level (LAeq)

DEFINITIONS

Audiometer

An audiometer is a frequency controlled audio signal generator. It produces a pure tone signal, the frequency and intensity of which are varied, for use in the measurement of hearing. [24]

Audiometric testing

Audiometry is the process whereby an individuals hearing threshold levels are determined over a specified range of frequencies. An audiometer is used to present a series of tones of varying frequency and loudness to each ear separately and the subject signals if the tone is heard. As a minimum requirement these should comprise 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. The extent of a persons hearing loss is measured.

Routine screening audiometry employs basic air conduction techniques to record baseline, periodic screening monitoring and exit audiograms. [24]

Decibel - dB

The unit used to measure how loud a sound is Decibel. The human ear is most sensitive to sounds at or near the centre of its frequency range. This provides the basis for the A scale weighting to assess the impact of noise on people. Sound generated at frequencies to which the ear is less sensitive has less impact on exposed persons, and A-weighting devalues the contribution of such noise to the overall level determined. A-weighting is in accordance with

the 40-phon (perceived) equal loudness curve. A-weighted levels are quantified in dB (A) [24, 25, and 26]

Instruction 171

This refers to the Compensation Commissioner's Circular Instruction 171 and Supplement entitled Determination of Permanent Disablement Resulting from Noise Induced Hearing Loss and Trauma

Equivalent continuous A -weighted sound pressure level (LAeq)

It is the mean of the sum of all different sound pressure levels which occur during the measurement period, taking into account the duration of each. It is the average noise energy over a period of time. [25]

Sensorineural

Sensory refers to the sense organ in the inner ear and neural refers to the nerve fibres. Sensorineural hearing loss can involve impairment of the cochlea, the auditory nerve or both. Sensorineural hearing loss is almost always irreversible. [19]

Threshold shift

Noise-induced temporary threshold shift refers to a temporary loss in hearing sensitivity. Hearing sensitivity will return to the pre-exposed level in a matter of hours or days without continued excessive exposure [19]

Tinnitus

A ringing, buzzing or swishing noise heard in the ears which often accompanies noise induced hearing loss, and suffers notice it most when the environment is quiet at night. [6]

CHAPTER 1

1 INTRODUCTION

1.1 Background

The pulp and paper industry includes mills that produce wood pulp, paper and paperboard and factories which convert paper and paperboard into thousands of finished products.

The company described in this study is a global pulp and paper company which manufactures a range of pulp and paper products which includes bleached hardwood pulp, newsprint, printing and writing papers and cardboard boxes.

Noise-induced Hearing Loss (NIHL) is particularly important as noise is the most common and growing occupational health hazard and can be hazardous in several ways. It is estimated that millions of people through out the world are affected. [(1)]

Continued or repeated exposures to high intensity sound can cause acoustic trauma to the ear resulting in hearing loss, ringing in the ears, occasional dizziness and non- auditory effects such as increases in heart rate and blood pressure. [(1)]

Exposure to intense noise results in loss of hair cells in the organ of Corti. Although persons vary greatly in susceptibility to NIHL, nearly everyone will lose some hearing if exposed to sufficiently intense noise for an adequate time. Any noise exceeding 85 decibel (dB) is damaging. Occupational noise is a significant cause of adult-onset hearing loss. [(2)]

Without hearing it is very difficult to lead a full and productive life on or off the job. Individuals with impaired hearing often experience social isolation and depression as well as physical problems. [3]

1.2 Noise and Health

NIHL occurs when any excessive sound energy strikes the inner ear and it causes a reversible, temporary auditory fatigue, technically known as a temporary threshold shift. If the noise is loud enough and the duration of exposure long enough, it may cause a permanent threshold shift. [2, 3, 4]

NIHL is defined as an occupational disease caused by either exposure to excessive noise in the workplace or by an occupational injury due to acoustic trauma causing the immediate loss of hearing produced by one or more exposures to sudden intense forms of acoustic energy such as explosions, gunfire or blasts – defined in Instruction 171.

In South Africa, hearing conservation is governed in the Noise-induced Hearing Loss Regulations (Occupational Health and Safety Act, 85 of 1993) and Internal Instruction 171 regarding compensation for loss of hearing (COID Act, 130 of 1993).

The first symptom of hearing loss is commonly an inability to hear another person speaking, especially in noisy surroundings and especially high pitch sounds (3000 to 6000 Hz). [5, 6, 7]

Tinnitus is a common complaint of workers who are exposed to noise. Phoon, Lee and Chia found that 23.3% of workers diagnosed with NIHL also had tinnitus. 30% of these workers with tinnitus complained that it interfered with daily activities like telephone conversation and sleep. [8]

Characteristics of NIHL include the following:

i. It is bilateral, symmetrical and sensorineural as it affects the hair cells in the inner ear.

ii. NIHL develops gradually, but most rapidly in the first 10 yeas of exposure.
iii. It starts in the higher frequencies (3000 – 6000 Hz) i.e. greater loss at these frequencies than at 500 – 2000 Hz. Given stable conditions losses at 3000, 4000 and 6000 Hz will usually reach a maximal point in 10 – 15 years.
iv. The greatest loss usually occurs at 4000 Hz. The audiogram has a characteristic “ski-slope” appearance. This notch at 4000 Hz deepens with additional years of exposure, but reaches a plateau after 15 – 20 years of exposure.
v. The high frequency hearing loss usually averages 50 – 70 d B. With additional years of exposure there is some spread of hearing loss to the lower frequencies, but the maximum loss at low frequencies is much less, usually not more than 20 d B. [9]

The National Institute for Occupational Safety and Health (NIOSH) in America estimates that prolonged exposure to noise at 100dB will result in 56 out of 100 workers suffering hearing loss; at 90dB, 29 workers out of 100 will suffer hearing loss and at 85dB, 15 out of 100 workers will suffer hearing loss. Even at 80dB, 3 out of 100 will suffer hearing loss. [3, 10,)]

Borchgrevink stated that hearing impairment continues to be the most prevalent disability in Western societies. NIOSH rates NIHL among the top ten work-related problems. Recent studies report that employees continue to develop NIHL in spite of occupational hearing conservation programmes. Noise seems to be an increasing hazard to hearing with current health promotion initiatives due to insufficiencies in these programmes. [4]

In a cross-sectional epidemiological survey carried out by Thierry and Meyer-Bisch in a car-body workshop with noise levels at 95 dB(A) audiometric results revealed significant hearing loss after 9 years of exposure. [11]

Maisarah and Said studied 524 industrial workers; 442 noise-exposed and 82 non-exposed workers. The prevalence of sensori-neural hearing loss was significantly higher amongst the noise-exposed group [12]

1.3 NIHL world wide

In countries such as Sweden 70% of construction workers do not have normal hearing, in Germany 70% of the population are “noise disturbed” and in Holland 1 million suffer from ill effects attributable to excessive noise levels from the nearby Schiphol airport. Of the roughly 40 million Americans suffering from hearing loss 10 million can be attributed to NIHL virtually all of which was preventable. Workers compensation claims for hearing loss increased two-fold during 1984 –1991 in Washington State. The economic cost of occupational hearing loss has been estimated to be in the billions of dollars. [5, 6, 4, 13,)]

In Finland NIHL is still the second most common work-related disease and the financial burden related to occupational hearing impairments includes costs of compensation, salaries of screening personnel, equipment, maintenance costs, and cost resulting from loss of work for the employer and referrals to specialist clinics. [15]

Brickner and Carel compared the rate of the development of NIHL in a group of 150 male workers exposed to industrial noise of over 85 d B (A) and found that the annual rate of decline in the exposed group for frequencies 1000-4000 Hz) was about 1 dB/year, it was less than 0.5 dB /year in the unexposed group. [14]

1.4 NIHL in the pulp and Paper industry

Paper mills typically generate noise levels between 98 and 107 dB (A) and it is well documented that if the noise is loud enough and the duration of exposure long enough that it may cause NIHL that is irreversible and for which there is no cure.

For Pulp mill workers noise is a stressful, annoying sound which presence is extremely noticeable and inescapable. Noise is mainly produced by fans, motors, flow of water and product inside equipment, pressurised flow of liquor in stock lines, high pressure transfer of steam through the digesters, scrubber fans and motors and soot blowing at the recovery unit. Noise producing activities at the workshops include hammering, angle grinding, and use of impact wrenches, pneumatic chippers and drills. (16)

Although operators often control the paper making process from dedicated noise refuges that create a quieter environment in which to work, there are times when operators need to work near machinery. In these areas the use of conventional noise control techniques e.g. silencers, enclosures, external damping, low noise emission gearing (silent drives) and the relocation of noisy ancillary equipment has been of limited success in reducing noise levels. (16)

Noise levels are measured between 98 and 107 dB(A) at the wet end of paper making machines. This is between 42 and 25 dB(A) higher than the noise levels in a refuge area. (16)

Lutman states that at 90 dB(A) and above the risk for hearing impairment becomes material, with the majority of individuals accruing a significant hearing impairment. (17)

Toppila et al. (2000) analysed the association of NIHL with various risk factors among 685 workers in forest, shipyard and **paper mills**. The mean hearing level at 4 kHz was 21.5 dB hearing loss. It correlated significantly with age, noise emission level and noise exposure level. (18)

Bergstrom and Nystrom, conducted a 20-year follow-up study on the development of hearing loss due to the fact that NIHL is responsible for the majority of occupational disease compensation payouts. During long-term exposure to occupational noise on 319 employees working in saw mills and **paper pulp production**, who were exposed to mean noise levels around 95–

100 dB (A) it was found that during the observation period mean hearing levels deteriorated slowly especially at 4 kHz [20]

1.5 NIHL in South Africa

In South Africa there are no accurate figures for the number of people who have hearing loss, or how many of these are as a result of exposure to noise in their working environment.

Instruction 171 of the Compensation of Occupational Diseases and Injuries Act, Act 130 of 1993 (COID Act) defines NIHL as an occupational disease "caused by either exposure to excessive noise in the workplace or by an occupational injury due to acoustic trauma causing the immediate loss of hearing produced by one or more exposures to sudden intense forms of acoustic energy such as explosions".

NIHL is a scheduled compensable disease in terms of schedule 3 of the Compensation for Occupational Injuries and Diseases Act. In 1991, 104 people were compensated for occupational disease of any kind. In 1997 this number increased to 3 615 and of these a staggering 1903 were for NIHL.
In South Africa NIHL is responsible for ± 15% of all compensation claims submitted to the assuror Rand Mutual, and accounts for ±45% of costs paid out by the Rand Mutual Assurance to claimants in the mining industry. Compensation paid out at one mine during the period June to October 1999 amounted to almost R 2 million. [19]

1.6 South African Pulp and Paper Industry

The forest products industry in South Africa is a major employer and has great importance to the South African labour market. It is estimated that about 120 000 people are employed in those industries which use wood as primary input, of which 30% is working in pulp and paper manufacturing. [21]

It is estimated that ± 40 000 workers are working in pulp and paper manufacturing in South Africa. This indicates that nearly 23 000 workers are at risk of developing NIHL. Not much is known about the prevalence of NIHL in paper mills in South Africa. [21]

An evaluation of noise, conducted by an approved inspection authority for noise within the working environment at the KZN Paper mill showed that 116 of 159 measurement areas had average noise rating levels that equalled or exceeded the 85 dB(A) statutory limit and therefore require the implementation of hearing conservation measures. These measures would include audiometric testing of the hearing of exposed employees on at least an annual basis. However the prevalence of NIHL amongst these workers is unknown.

The mill has a hearing conservation programme that consists of the following elements. The first is noise reduction at source if practicable possible; as this approach, however costly offers the greatest potential for reducing the risk of NIHL. This includes a buy quiet policy. It further includes risk assessments by occupational hygienists, education and training in hazard awareness, noise surveys with the demarcation of noise zones, the provision of suitable hearing protection devices and risk based medical examinations.

1.7 Motivation for this study

A lack of knowledge about this particular topic in the South African Pulp and Paper industry lead to this study as not much is known about the prevalence of NIHL in paper mills in SA.

Audiometric tests are performed for legal compliance and compensation purposes. Medical surveillance results are not analysed and utilized as an integral part of the risk management programme for the prevention of NIHL. Feedback regarding deterioration in hearing is not provided consistently to line management to enable them to evaluate the effectiveness of their hearing conservation program.

The compensation history in this particular pulp and paper mill reveals that since the year 1999 twenty seven cases of NIHL were reported by the company to the Compensation Commissioner and compensation paid out in the amount of R 634, 769.17

The study was undertaken in order to determine the extent to which the exposed workers are suffering from hearing loss that could be ascribed to excessive noise exposure. The significance of the study lies in the fact that with advising management on the prevalence of NIHL according to type and area of work as well as the need for the implementation of specific control measures the progression of NIHL will be prevented.

1.8 Research Objectives

The purpose of the study was to describe the prevalence of NIHL in production and maintenance workers in a pulp and paper mill in KZN South Africa in relation to duration of service and occupation and to grade the severity of hearing loss according to categories of percentage loss of hearing (PLH).

The aim was to establish whether hearing loss, which could be ascribed to excessive exposure to noise, is present in production and maintenance workers.

The hypothesis was that exposure to excessive noise causes NIHL in maintenance and production workers in a paper mill in KZN South Africa.

It was a cross sectional study and entailed a retrospective review of medical records of employees working in the paper mill. The study population consisted out of all production and engineering workers.

1.9 Exclusion criteria

Workers who were relocated to a different section / business unit during employment were excluded in the calculation of the prevalence for the specific business unit.

In conclusion, noise is a well recognised significant health hazard that is on the increase with no accurate data available on the prevalence of NIHL in the pulp and paper industry.

CHAPTER 2

2 MATERIALS AND METHODS

2.1 Selecting study setting

This is a descriptive study involving a retrospective, cross sectional review of audiometry records in the largest and most modern paper mill in South Africa.

The mill was chosen as the principal investigator is an employee and access to the required medical records was easy. Obtaining informed consent from employees was not difficult as the principal investigator is a member of the occupational health team and a trusting relationship already existed.

2.2 Study setting: KZN Paper mill

The paper mill selected in this study comprises the following sections or business units: wood yard, chemical plant, power and recovery, pulp mill, paper machines and the engineering department.

Process

The Kraft process which means strength in German is used**.** It involves the cooking of wood chips in a solution of sodium hydroxide and sodium sulphide called cooking liquor. The alkaline attack causes the lignin molecules in the wood which bond the fibres to fragment into smaller segments. These smaller molecules are then soluble in alkali liquor and can be removed from the wood, thus leaving the wood fibres (pulp) [22]

The fibrous raw materials used in the Kraft process in South Africa are soft woods (pine) and hardwoods (eucalyptus and wattle) and are normally transported to the mills as logs. Hardwoods are brought into the mill without the bark and softwood timber must be de barked at the mill by a drum

debarker. The logs are chipped into pieces, called wood chips that are small enough for the cooking liquor to penetrate them and release the fibrous part of the wood to form pulp for further processing. (22)

The chips are cooked in the **pulp mill** in a digester filled with cooking liquor, once the wood has been cooked and blown into the blow tank the spent cooking liquor is removed through pulp washing. After the pulp has been washed it is screened for contaminants such as uncooked chips, wood knots, stone, wire etc. that must be removed. After the cleaning process and removing the contaminants, the pulp is bleached by chemically treating it to alter the coloured matter and to impart a higher brightness to the pulp. (22)

Organic material extracted from the chips and the inorganic cooking chemicals is stored in large tanks at the liquor recovery plant. To recover the inorganic chemicals the organic portion is burnt off in a furnace. The Recausticizing process at the chemical plant converts the chemicals recovered in the recovery boiler to their original form when they were used for cooking the pulp. (22)

The mill has two paper machines and each consists of 4 basic sections: *Wet end*: the papermaking fibres are distributed uniformly onto a forming wire with water draining through the wire to create sheet formation. Water drains out of the sheet through gravity and vacuum created by vacuum pumps. *The press section*: the main purpose is to remove additional water and to consolidate the sheet. The press section is equipped with felt which assists in the removal of the water by absorption. Vacuum boxes are also used to remove the water that has been absorbed by the felt. *Dryer section* where the removal of liquid water from the sheet takes place by evaporation as the sheet is exposed to both intermittent application of heat and varying rates of vapour removal through the dryers. The sheet is brought into contact with the hot surface of the drying cylinders alternating the contact side of the sheet. Temperatures of the cylinders vary from the first to the last section, having a lower surface temperature in the first section and increasing to the last. The final step is *winding* the sheet onto a large reel, known as a jumbo. After winding the

jumbo is removed from the paper machine and transferred to other equipment such as the supercalender to be prepared for shipment to customers. [22, 23]

Production operators (panel and area) operate the different sections of the plants. The engineering department consists of mechanical, electrical and instrumentation engineering workshops responsible for plant and control systems maintenance.

2.3 Hearing Conservation Programme

To prevent NIHL and to comply with legislation the mill has a hearing conservation programme in place that includes the following components: [26]

1. Health risk assessments; including activities, levels and duration of exposure, evaluation of control measures and the use of personal dosimetry to determine exposure levels.
2. Noise surveys for hearing conservation purposes to determine the degree of hazardous noise exposure by surveying any area in which workers are likely to be exposed to hazardous noise (>85 dB (A)) every two years. Noise zones are demarcated.
3. Training and information; A hearing conservation training programme is in place and form part of the mill induction programme.
4. Controls:
    i. Receptor control based on the use of personal protective equipment, supervision and enforcement. The noise reduction ratio (NRR) of hearing protective devices (HPD) in use is checked against specific plant noise levels to ensure sufficient attenuation. The standard that has been implemented by the mill is a NRR of 30. The engineering department has been issued with Noise Clippers™ (customised hearing protective device) that has been calibrated to attenuate noise at 120 dB.
    ii. Engineering controls are undertaken to reduce exposures to < 85 dB(A) and include: design of

equipment, selection of quieter machines, proper maintenance and isolation of the worker from noise sources if possible.

iii. Noise reduction is considered when planning new projects or when purchasing new equipment.

iv. A buy-quiet policy for new equipment acquisitions has been adopted and is implemented when reasonably practicable.

2.4 Medical surveillance programme

Audiometry is carried out at the pre-placement examination, at periodic intervals thereafter (as described below) and on exit from the company. Counselling and education is also provided at these examinations.

Audiometric surveillance is conducted on all employees exposed to noise at or above the noise-rating limit 85 dB (A) in accordance with instruction 171.

Workers exposed to noise levels in excess of 105 dB(A) are tested every 6 months and workers exposed to noise levels in excess of 85 dB(A) and less than 105 dB(A) are tested on an annual basis.

Workers diagnosed with NIHL are recorded in an electronic incident register and followed-up by the occupational hygiene technologist employed by the mill. The workers are counselled in hearing conservation measures and their hearing protection evaluated for suitability.

2.5 Study population

The study population was selected based on their type of work and exposure to noise and consisted of 541 noise-exposed production and engineering workers. The entire population was sampled and did not require calculation of sample size for the study.

2.6 Measurement tool

The principal investigator did not carry out any measurements, as data was obtained from records of medical surveillance performed at the company clinic.

The measurement tool used entailed the study and evaluation of individual audiograms and application of specific diagnostic criteria to make the diagnosis of NIHL. The diagnosis was confirmed by the Occupational Medicine Practitioner employed with the company.

The characteristics of NIHL include the following: [9]

i. It is bilateral, symmetrical and sensorineural as it affects the hair cells in the inner ear.
ii. NIHL develops gradually, but most rapidly in the first 10 years of exposure.
iii. It starts in the higher frequencies (3000 – 6000 Hz) i.e. greater loss at these frequencies than at 500 – 2000 Hz. given stable conditions losses at 3000, 4000 and 6000 Hz will usually reach a maximal point in 10 – 15 years.
iv. The greatest loss usually occurs at 4000 Hz. The audiogram has a characteristic “ski-slope” appearance. This notch at 4000 Hz deepens with additional years of exposure, but reaches a plateau after 15 – 20 years of exposure.
v. The high frequency hearing loss usually averages 50 – 70 dB. With additional years of exposure there is some spread of hearing loss to the lower frequencies, but the maximum loss at low frequencies is much less, usually not more than 20 dB.

Criteria used to diagnose NIHL

i. An audiogram with a typical notch (ski-slope appearance) bilaterally, indicating a decrease in threshold of at least 25 dB at 4 or 6 kHz.

ii. As per Instruction 171 of the COID Act: Using the approved frequency specific tables the sum of the hearing losses at 500, 1000, 2000, 3000, 4000 Hz was calculated from an audiogram. This is the percentage loss of hearing (PLH) used to assess the incapacity due to it.

iii. The PLH was determined according to the look up tables provided in Instruction 171 of the COID Act.

iv. The company appointed Occupational Medicine Practitioner verified the diagnosis of NIHL.

Audiograms were categorized for severity using 3 categories: 5% and less; 5.1 - 9.9% and 10% and more. Only deterioration by 10% or more from the initial PLH would be compensable.

2.7 Calibration and Quality Control

The data used by the principal investigator was obtained in the clinic through the following audiometric procedures and by applying the following standards:

Table 1: APPLICATION, PURPOSE AND PROCEDURAL REQUIREMENTS FOR AUDIOMETRIC TESTING [24]

Type of Audiometry	Application	Purpose	Procedural requirements
Periodic screening	Annually for noise exposed individuals (TWA -> 85dB)	To quantify any permanent hearing loss that results from exposure to noise	Before testing a 16 hour period with no exposure to noise >85dB Use of HPD complying with SABS 1451-1, 2 or 3 as appropriate is acceptable

Table 2: AUDIOMETER REQUIREMENTS [24]

Type of audiometer	Test frequencies	Specification
Screening	0.5; 100; 2000; 3000; 4000; 6000; 8000 Hz	Type 4 (IEC 60645-1)

An audiometer is a frequency controlled audio signal generator. It produces a pure tone signal, the frequency and intensity of which are varied for use in hearing measurement. Audiometry is used to determine hearing thresholds for

both pure tone and speech by air conduction. The equipment is calibrated according to American National Standard Institute (ANSI) standards specification for audiometers (ANSI S 3.6 1996) [24]

The acoustic enclosures for screening audiometry comply with the relevant requirements for background noise and environmental conditions stipulated in SANS 0182: 1998. This standard provides background noise limits. [24]

The screening audiometers have a valid calibration certificate. On site electro acoustic calibrations are performed annually in accordance with SANS 0154:1996 and the calibration service provider can demonstrate traceability to the National acoustics standard.

Personnel conducting audiometry confirm the accuracy and calibration continuity of screening audiometers on a weekly basis by means of a biological calibration check.

Table 3: REQUIREMENTS FOR PERSONNEL CONDUCTING AUDIOMETRIC TESTS

Screening Audiometry
Baseline, periodic screening, monitoring, exit
Registered with the Professional Society for Occupational Health Nursing Practitioners as an audiometrist

Audiometric testing was preceded by instruction in the procedures and a familiarisation phase to confirm worker competence, by observing responses to preliminary test signals.

The test phase followed during which hearing threshold levels were measured and recorded. According to ISO 6189 the ascending method is recommended.

2.8 Data collection

Data was collected and captured onto an Excel spreadsheet and included; audiogram results in PLH at pre-placement and the year 2005, company number, age, sex, diagnosis with NIHL, employed with NIHL, PLH Category,

redeployed to another business unit during employment, duration of service, occupation and business Unit.

Microsoft Excel was used to calculate the percentage loss of hearing (PLH) from pre placement to 2005 and the category of hearing loss. The age group and years of service were also calculated. Data analysis included frequency tables and bar charts for discrete variables; for NIHL by severity, type of work and duration of service.

Data were analysed using Microsoft Excel and SPSS (Statistical package for social sciences)

The principal investigator did not carry out any measurements, as data was obtained from records of medical surveillance performed at the company clinic.

2.9 Quality control

Reliable quality data was ensured by the fact that audiograms were conducted in the same booth, under the same conditions and using the same software (Everest programme, Version 2.04.1.80.311, Serial number R046005). Quality checks according to Instruction 171, SANS code 0157:1996 and the internal standard operating procedure further ensured quality data.

The procedure entailed the following:
Acoustic seals on doors fitting properly and not perished, the earphone headbands are functional and tensioned to ensure a good fit for all heads, the earphone cushions are clean and undamaged, the response button is working with light flashing during the test, the absence of background noise and the absence of unwanted sounds at a minimum of three hearing level or loudness

settings for all test frequencies. The weekly biological calibration results are acceptable if less than 10 dB difference at any of the measured frequencies.

The principal investigator collected the data from the original audiogram, data was personally entered and verified by the company appointed occupational medicine practitioner.

2.10 Ethical considerations

Strict adherence to confidentiality of all medical records was ensured and access thereto was limited to medical personnel only. Workers signed an informed consent form.

Several mechanisms were used to ensure anonymity of participants and entailed the following:

Each participant was given a number. The master list of participant names and matching code numbers were stored separately. The list of actual names was destroyed and only group data was reported.

The risk-benefit was considered and no risk to the participants such as physical or psychological harm or loss of privacy existed.

2.11 Response rate

All 541 invited workers agreed to participate and gave informed consent and their medical data was used (i.e. 100% response rate)

CHAPTER 3

3 RESULTS

The aim of this study was to establish whether hearing loss, which could be ascribed to excessive exposure to noise, is present in production and maintenance (mechanical and automation engineering) workers.

During the study 932 individual audiograms were studied; evaluated and specific diagnostic criteria applied to make the diagnosis of NIHL on 466 participants. NIHL was grouped by degree of severity as described in chapter 2 under measurement tool.

In this chapter audiometry results are presented in business units; according to category of work, duration of service and age group.

3.1 Study Population

3.1.1 Gender distribution

The population was male dominant (99.5%) the only females were in the wood yard, pulp mill and technical department. The number of woman was so small that separate analysis was not possible. Refer to *Table 7and figure 1*

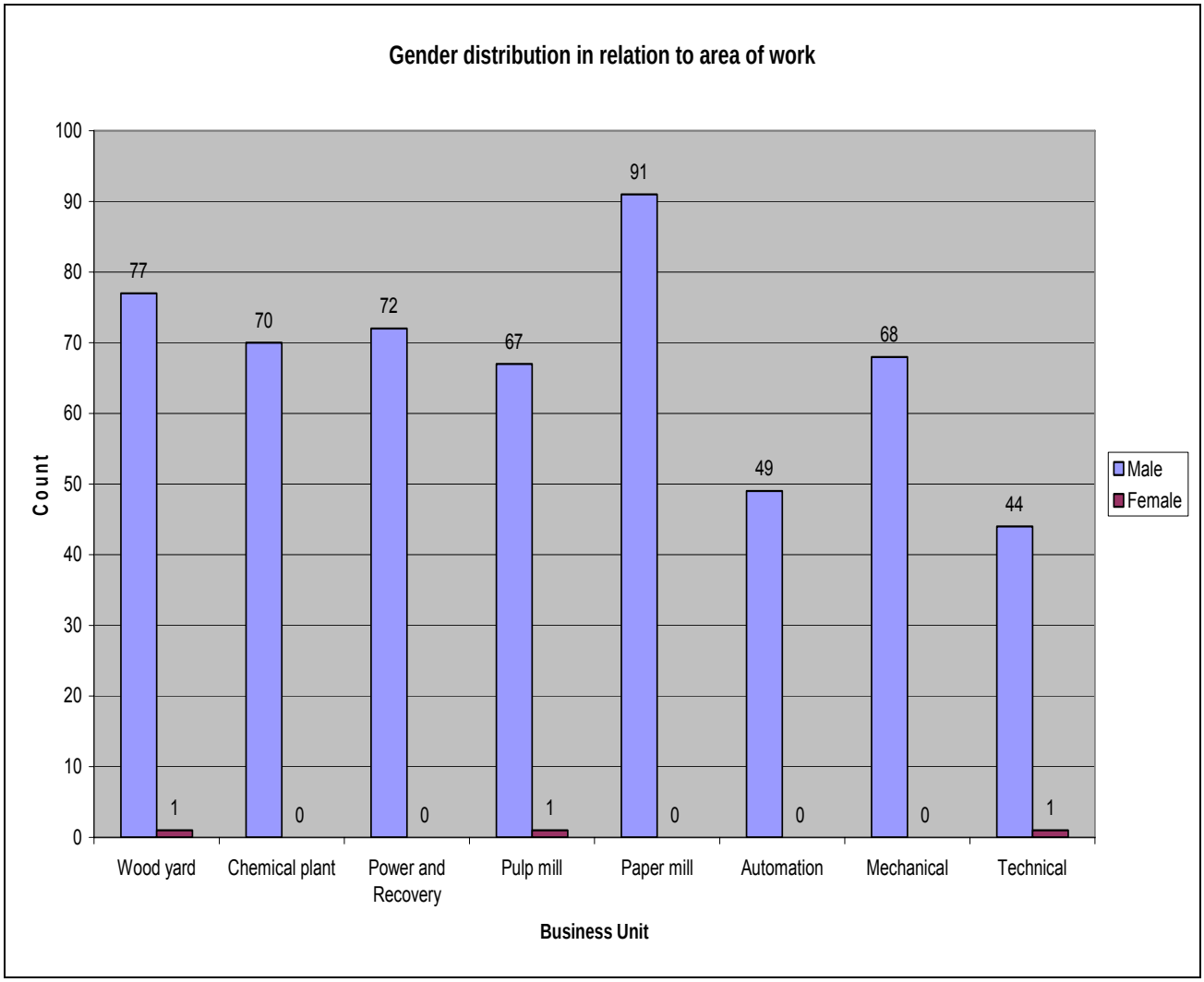

Figure 1: Gender distribution in relation to area of work

3.1.2 Re-deployment of workers

Seventy five workers (13.9%) have been re-deployed to another business unit since employment. Refer to *Table 8*

There was a significant association between re-deployment and business unit with the p-value less than 0.05

40% of workers in Power and Recovery have been re-deployed since employment.

3.1.3 Years of service

Nearly 75% of the participants had more than 10 years of service.

The data range is 21 and the mean 15 years service, the median 17.0 and the standard deviation 6.70. The data is negatively skewed (-.51) and not normally distributed. Refer to *Table 9*

There was a significant association between years of service and business unit with a p-value less than 0.05.

3.1.4 Age distribution

Two thirds of the study population is 40 years and older. The data range is 41 and the mean 43 years of age, the median is 44.0 and the standard deviation is 9.159. The data is negatively skewed (-.26) and not normally distributed.

There was a significant association between age and business unit with the p-value less than 0.05 Refer to *Table 10 and figure 2*

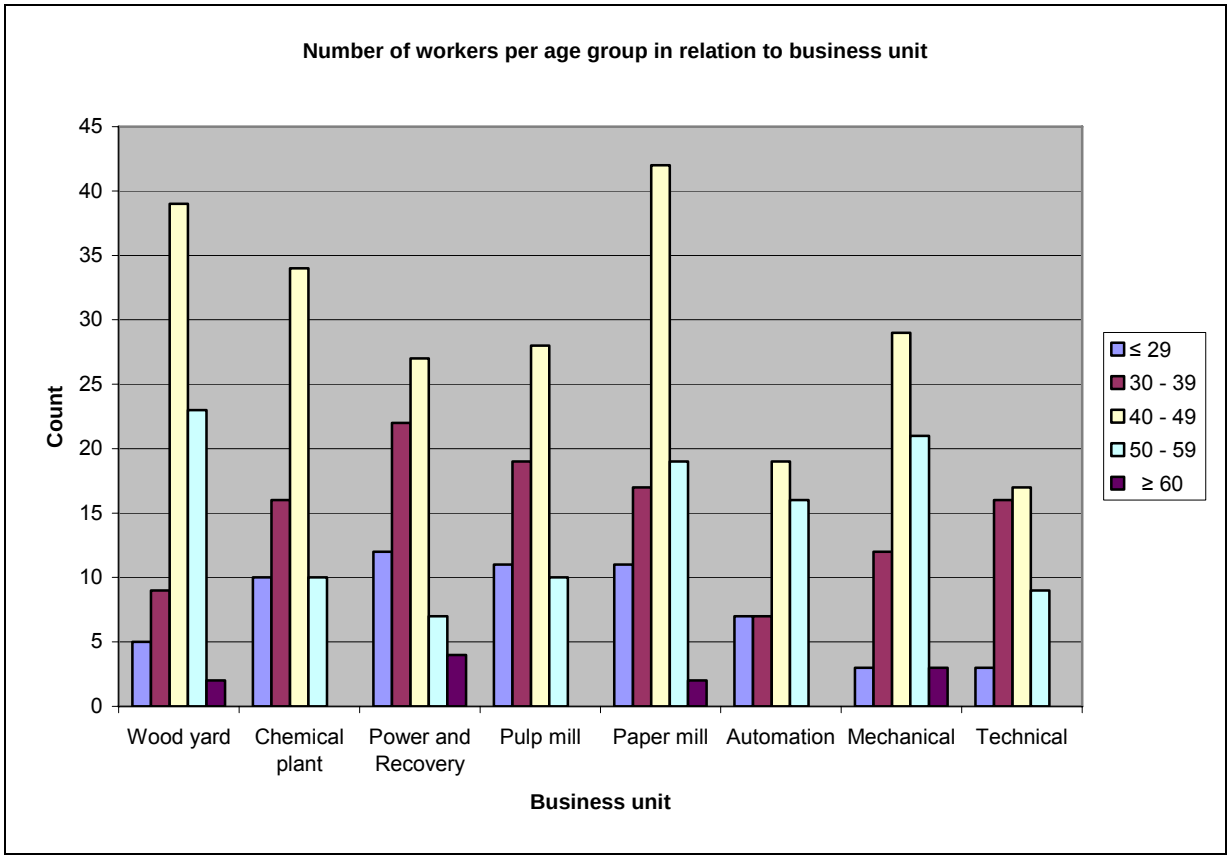

Figure 2: Number of workers per age group in relation to business unit

3.1.5 Type of work

The work force is divided into eight different areas of work (business units) according to production processes with the technical business unit the smallest. Maintenance work maybe carried out by dedicated mechanical and automation departments but there are also maintenance workers in the other business units.

The various occupations were divided into type of work and categorized as either production or engineering, with 65% of workers in the production category. Refer to *Table 11 and figure 3*

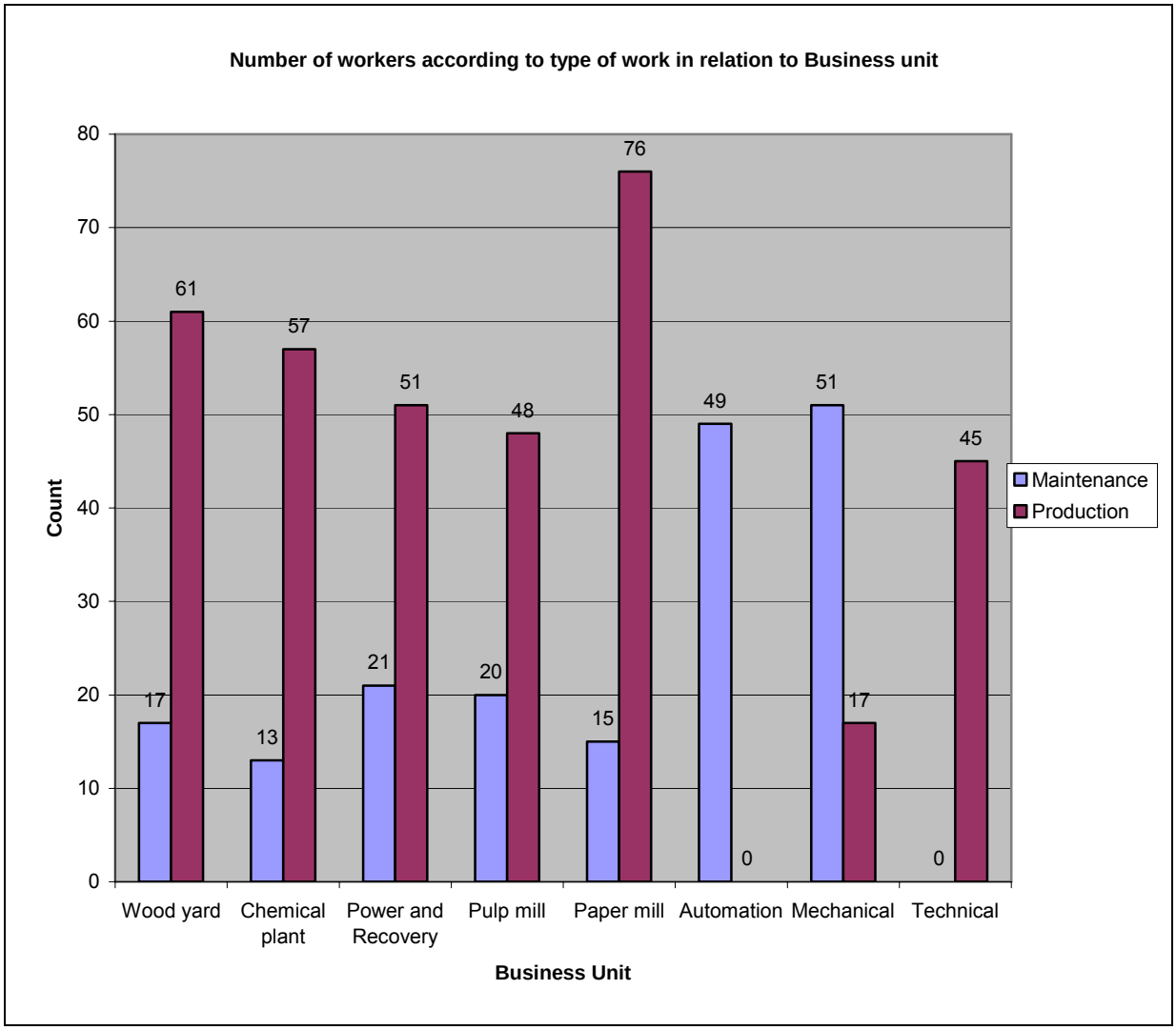

Figure 3: Number of workers according to type of work in relation to business unit

3.2 NIHL in relation to business unit

Seventy five participants were re-deployed since employment and were excluded. 98 audiograms met the criteria for the diagnosis of NIHL leaving 368 which did not. There was a significant association between the diagnosis of NIHL and area of work with a p-value of less than 0.05. Refer to *Table 12 and figure 4 and 5*

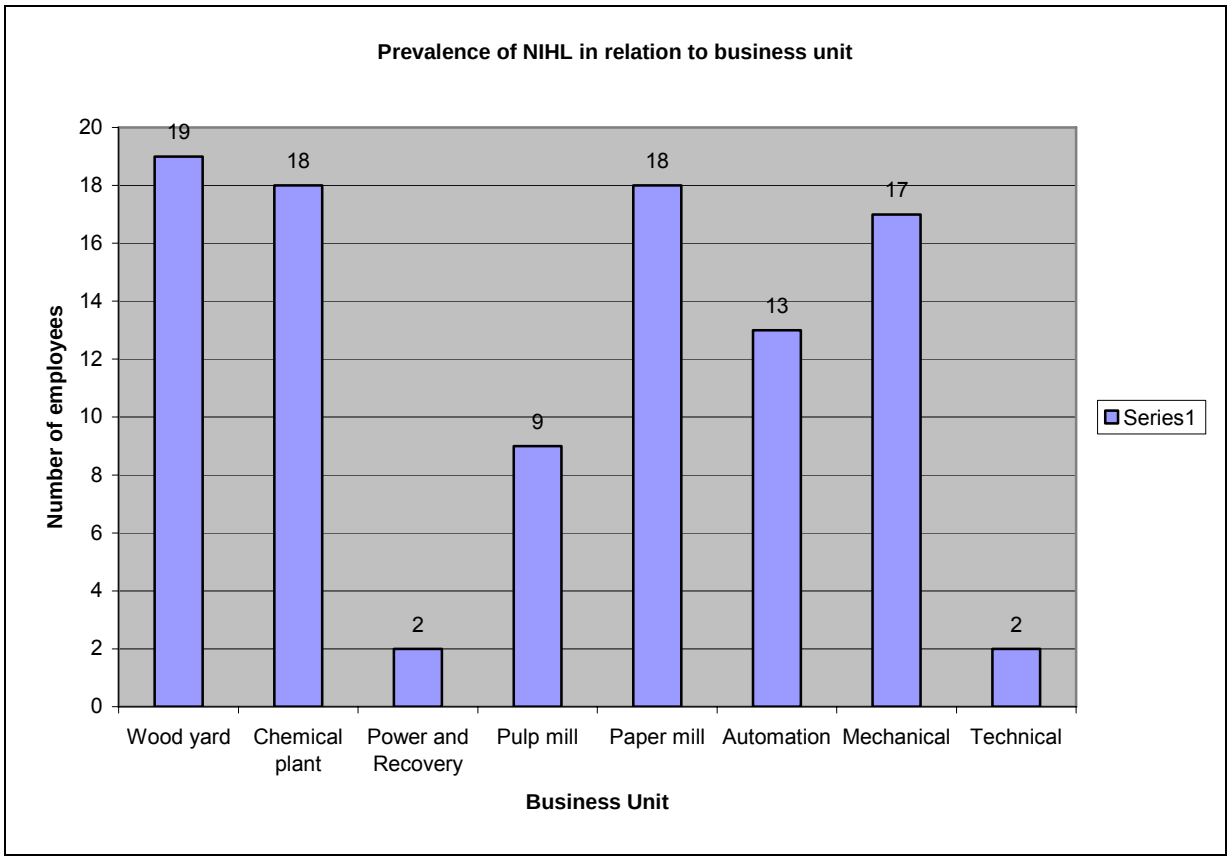

Figure 4: Prevalence of NIHL in relation to business unit

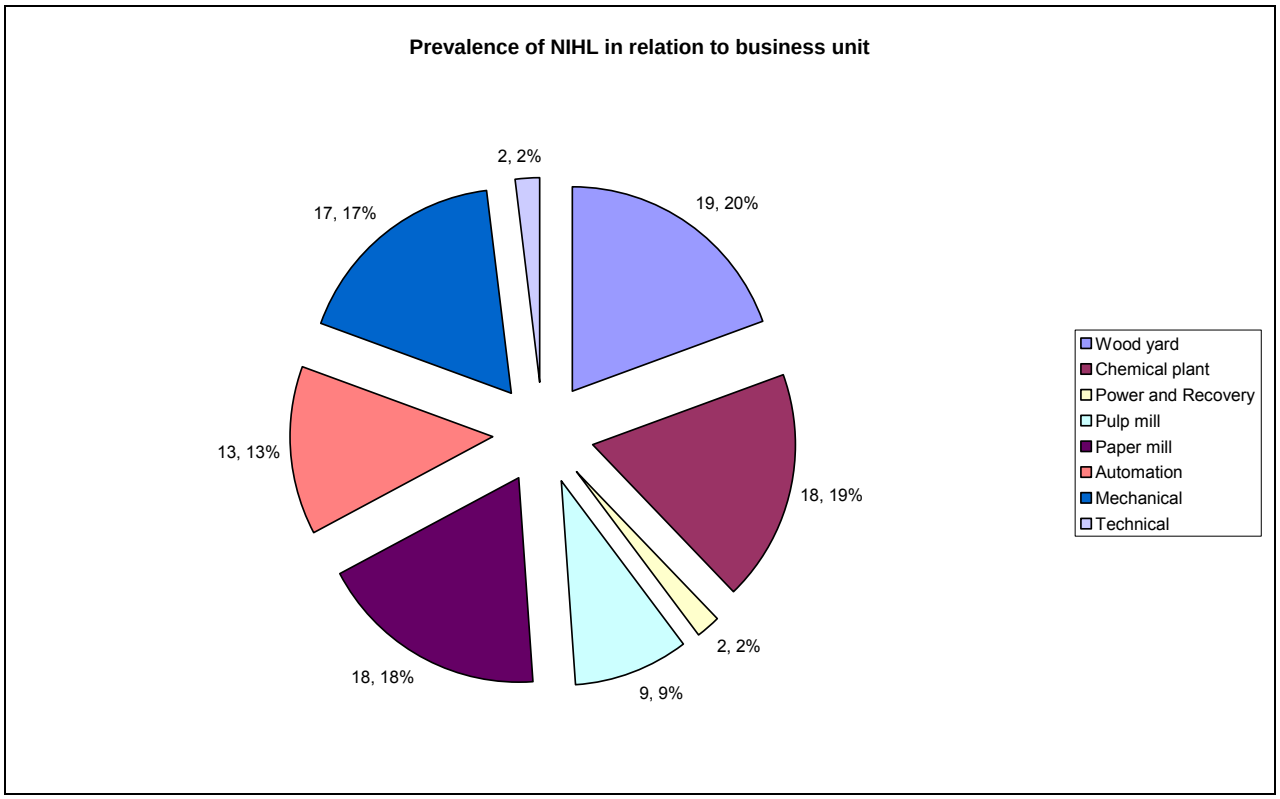

Figure 5: Prevalence of NIHL in relation to business unit

3.3 NIHL in relation to type of work and business unit

The prevalence of NIHL in relation to type of work indicated that; 52 (11.2%) maintenance workers and 46 (9.8%) production workers were diagnosed with NIHL. Refer to *Table 13*

There was a significant association between the diagnosis of NIHL and the type of work with a p-value of less than 0.05.

In calculating the prevalence of NIHL in relation to type of work and business unit it was found that for maintenance work there was no association between NIHL and business unit with a p-value greater than 0.05.

However; there was a significant association between NIHL, production work and business unit with a p-value less than 0.05. The highest prevalence of 20.6% was in the CHEMICAL PLANT (Refer to *Table 14 and figure 6)*

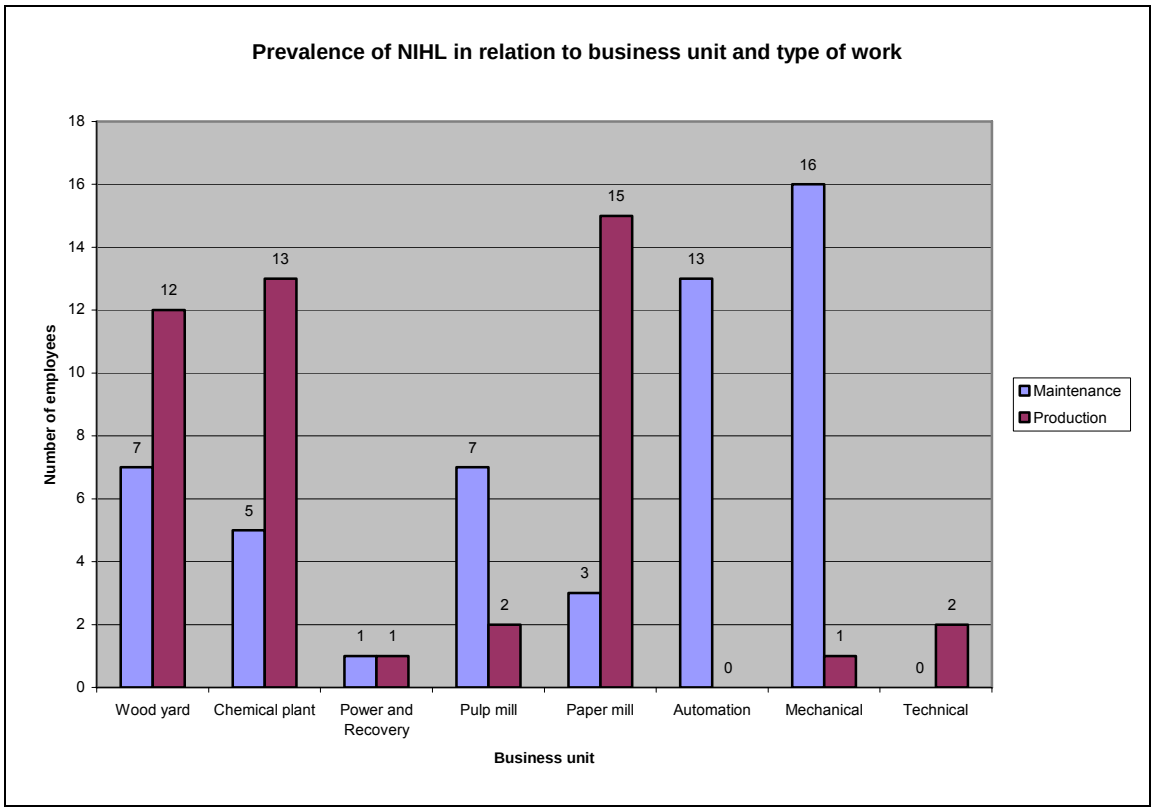

Figure 6: Prevalence of NIHL in relation to business unit and type of work

3.4 NIHL in relation to age and business unit

Concerning the prevalence of NIHL in relation to age the following results were found; the prevalence of 9.0% in the age group 40 – 49 was the highest with 8.0 % in the age group 50 – 59. Refer to *Table 4*

The p-value is less than 0.05 and a significant association between age and the prevalence of NIHL was found.

Table 4: PREVALENCE OF NIHL IN RELATION TO AGE

Age Category	NIHL	No NIHL	Total
29 and below	3 (0.6)	51 (11.0)	54
30 - 39	11 (2.0)	85 (18.0)	96
40 - 49	44 (9.0)	159 (34.0)	203
50 - 59	39 (8.0)	67 (14.0)	106
60 and above	1 (0.2)	6 (1.2)	7
N	98 (21.0)	368 (79.0)	466 (100.0)

$X^2 = 29.183$
df = 4
P-value = 0.00

In calculating the prevalence of NIHL in relation to age group and business unit; within the age group 50 – 59 in the business unit AUTOMATION the prevalence of 19.0 % was the highest. The WOOD YARD followed with a prevalence of 14.0% for the same age group. Refer to *Table 15 and figure 7*

No association between NIHL, age and business unit was found with the p-value greater than 0.05.

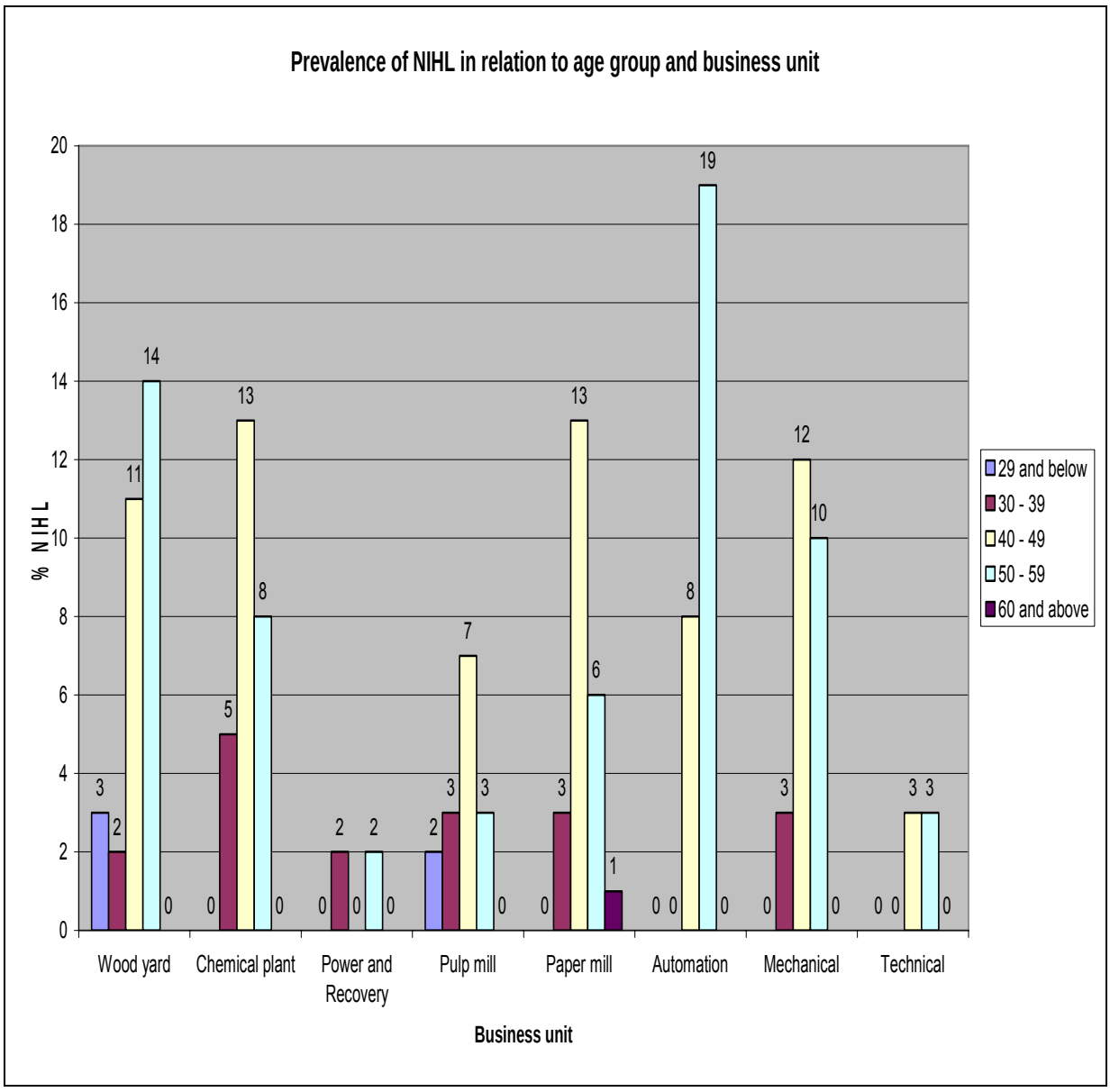

Figure 7: Prevalence of NIHL in relation to age and business unit

3.5 NIHL in relation to years of service and business unit

Calculating the prevalence of NIHL in relation to years of service the following results were found; the prevalence of 9.4 % for the group 10 – 20 years of service was the highest. Refer to *Table 16 and figure 8*

A significant association between NIHL and years of service was found, with a p-value of less than 0.05.

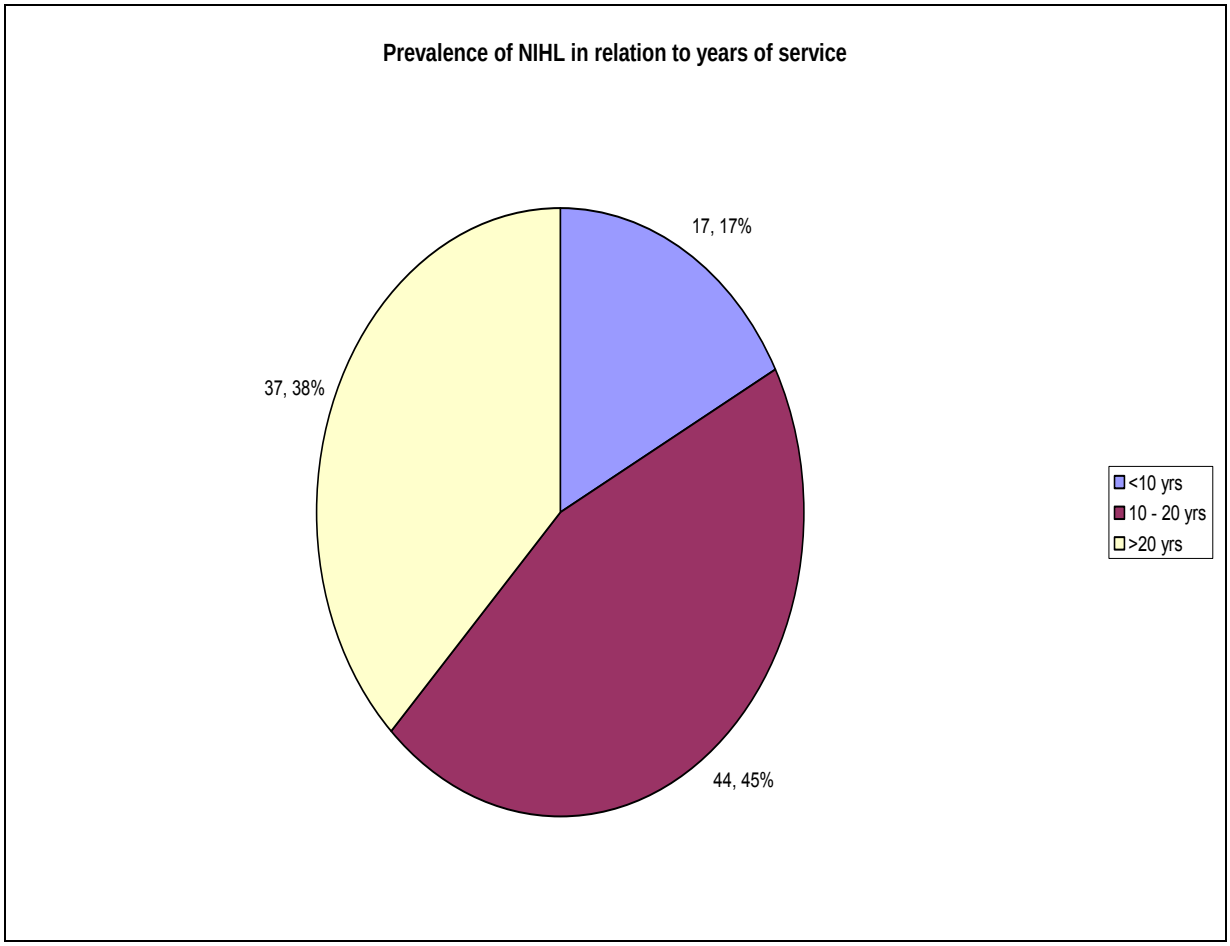

Figure 8: Prevalence of NIHL in relation to years of service

In calculating the prevalence of NIHL in relation to years of service and business unit it was found that the prevalence was the highest in the business

unit WOOD YARD with a prevalence of 18.2 % and in the business unit MECHANICAL 11.8 %. Refer to *Table 17 and figure 9*

There was no association between NIHL, years of service and business units with a p-value greater than 0.05.

However in the business unit POWER AND RECOVERY the association was significant with the p-value less than 0.05.

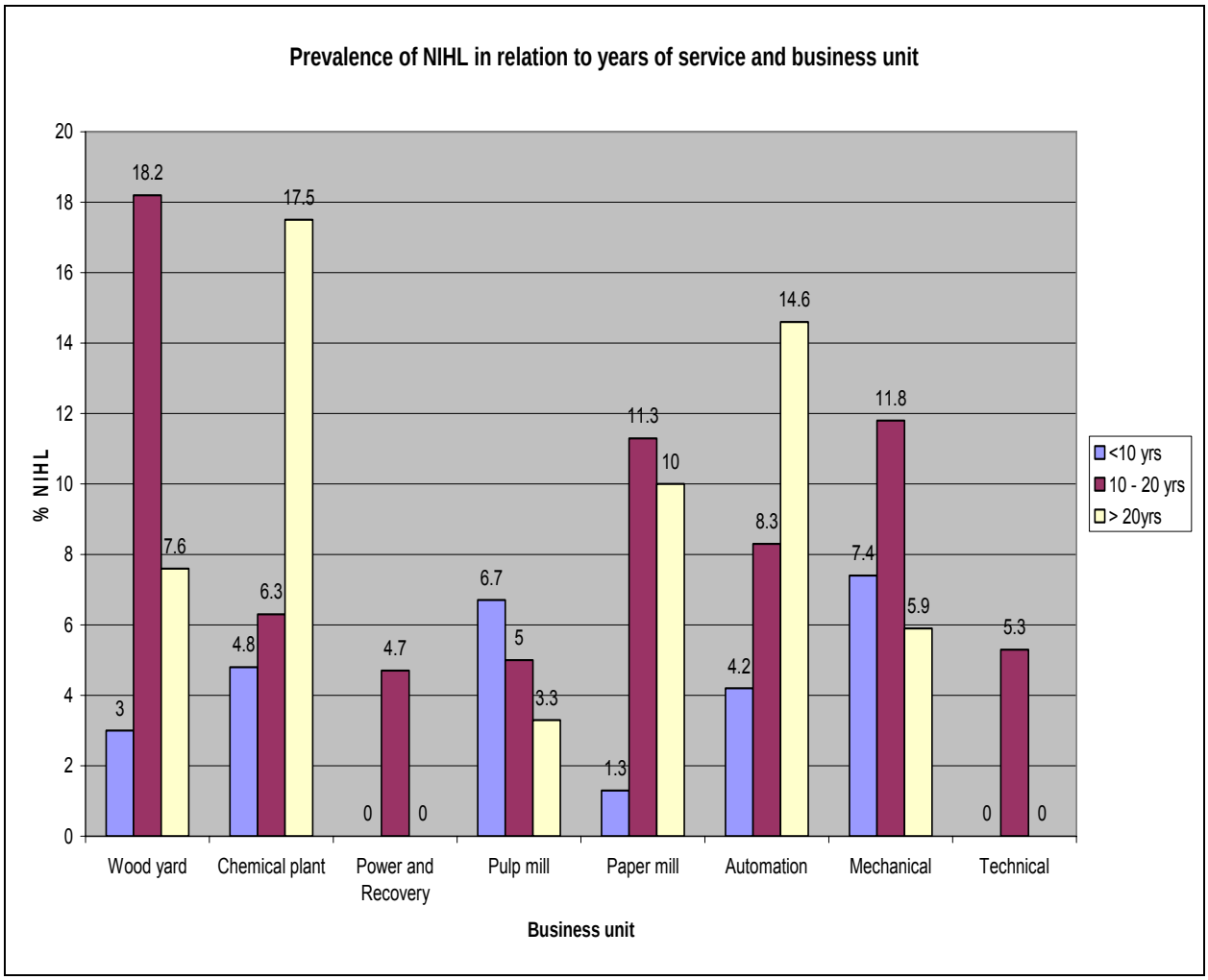

Figure 9: Prevalence of NIHL in relation to years of service and business unit

3.6 NIHL in categories of severity in relation to business units

Audiograms were classified into 3 groups according to the percentage loss of hearing (PLH) namely: ≤ 5, 5.1 – 9.9 and 10 and above. The prevalence was the highest with 78.8 % in the category ≤ 5 PLH. The lowest prevalence was in the category ≥ 10 PLH with a prevalence of 6.6 (Refer to *Table 18 and figure 10)*

In the category ≤ 5PLH it was found that the prevalence was the highest in the business unit CHEMICAL PLANT with a prevalence of 23.8 %

An association between severity and area of work (business unit) was found with the p-value for NIHL less than 0.05.

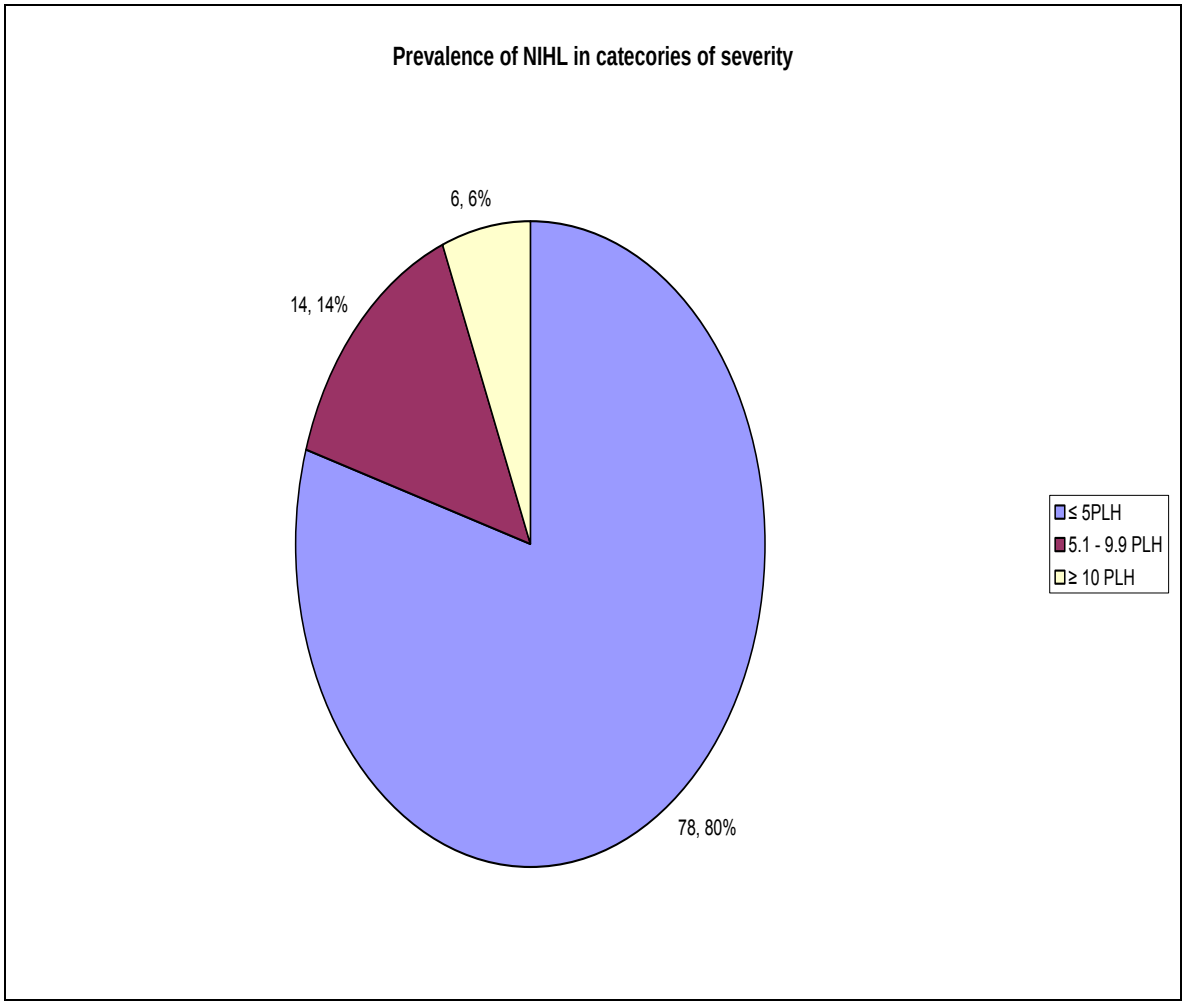

Figure 10: Prevalence of NIHL in categories of severity

3.7 NIHL in categories of severity in relation to age

In calculating the prevalence of NIHL according to categories of severity in relation to age, it was found that the prevalence was the highest in the age group 50 - 59 and in the category ≤ 5 PLH. (Refer to *Table 19 and figure 11)*

An association was found between age and severity with the p-value less than 0.05.

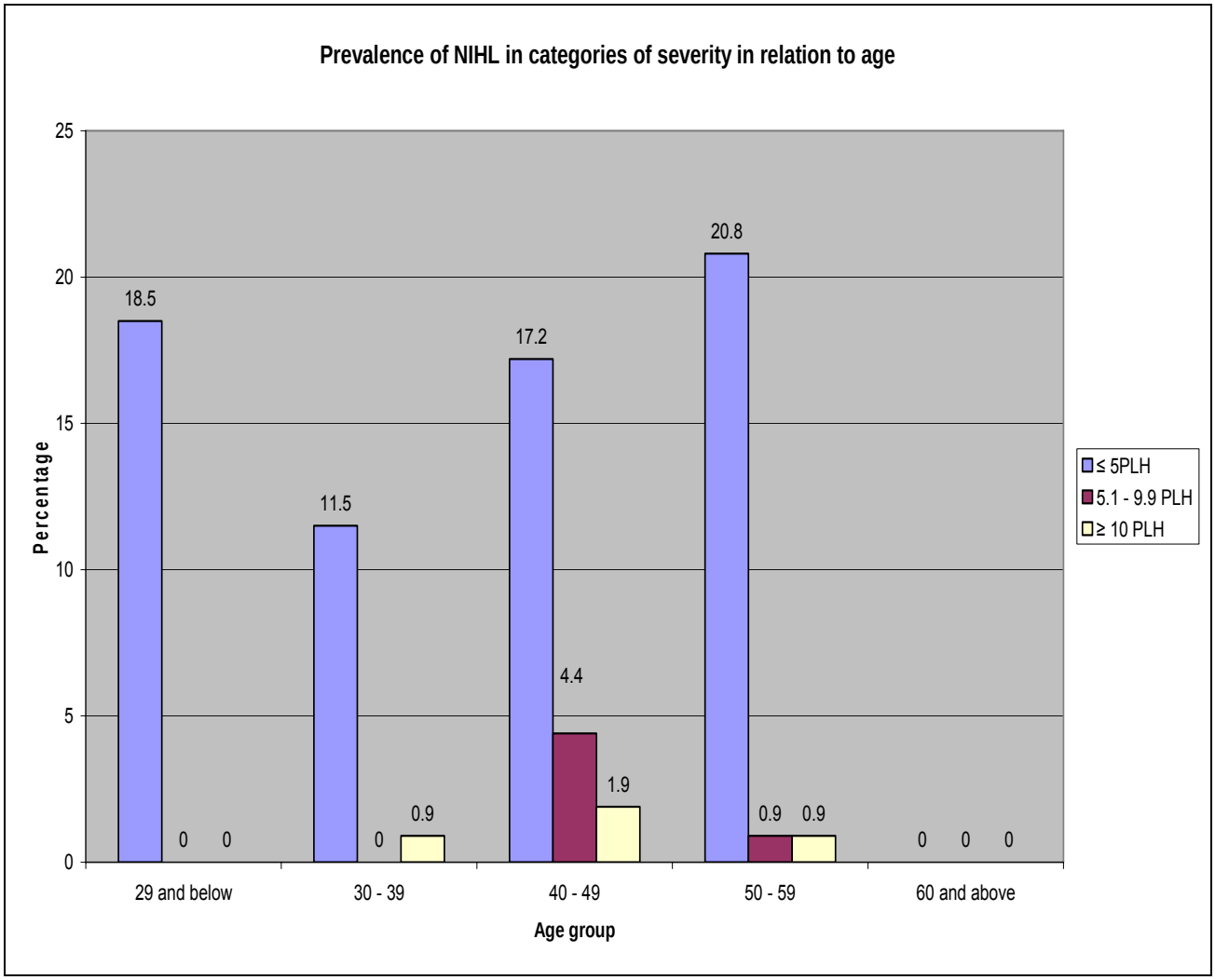

Figure 11: Prevalence of NIHL in categories of severity in relation to age

3.8 NIHL in relation to age and years of service

The prevalence of NIHL in relation to age and years of service was the highest in the age group 40 – 49 in the < 10 years service group.

The presence of NIHL is positively correlated with age and years of service. Refer to *Table 20*

CHAPTER 4

4 DISCUSSION AND CONCLUSION

The study was undertaken in order to determine the extent to which exposed workers are suffering from hearing loss that could be ascribed to excessive exposure to noise, and to describe the NIHL by severity, type of work, area of work and duration of service.

The sample size was 466 workers after the 75 re-deployed workers were excluded. The sample included all noise exposed workers in the pulp and paper mill and did not require the calculation of sample size.

Limitations

In consulting the Human Resources Management System (HRMS) Support Auditor at the Human Resources (HR) department it became evident that HR data is only available from June 1999, as the company has moved systems many times since start up of the mill in 1984 and they don't have access to the data. Between June 1999 and June 2006 the mill had 424 terminations, including workers that were not noise exposed. Refer to *Table 5*

Table 5: EMPLOYEE TERMINATION IN RELATION TO REASON

REASON	TOTAL
Resignations (personal reasons)	223 (52.6)
Retirement	52 (12.3)
ill health retirement	9 (2.1)
Dismissal	59 (13.9)
Retrenchment	45 (10.6)
Deaths	36 (8.5)
N	424 (100.0)

The total number of workers still employed since June 1999 is 57.4%. Only 2.1 % of workers left employment due to ill health with 8.5 % due to deaths. No detailed information regarding the course of death is available. No worker to date has been relocated or retrenched due to NIHL. The healthy worker effect should not play a role.

Only 5% of workers reported that they are involved with noisy hobbies. Refer to *table 6*

Table 6: NOISY HOBBIES

NOISY HOBBIES	NO NOISY HOBBIES	N
27 (5)	514 (95)	541 (100)

The prevalence of NIHL for the pulp and paper mill in this study was 21% (98/466) with 79% (368/466) of workers whose audiograms returned results not indicating NIHL.

In analyzing and describing the data the following were found:

There was a positive association between the diagnosis of NIHL and area of work. The Wood Yard, which represents the chipping operation in the mill, had the greatest prevalence at 28.8%; a contributing factor might be that noise levels in the wood room; the area where the wood logs are chipped exceeds 95 dB and most of the shift is spend outside the control room area. This correlates with a study done by NIOSH who estimated that at 90 dB 29 workers out of a 100 will suffer from hearing loss. [3, 10]

There was also a positive association between the type of work and the development of NIHL with maintenance workers being at the higher risk. The study showed that NIHL was significantly associated with both type and area of work; 52 (11.2%) maintenance workers in the study developed NIHL and

are at a greater risk due to their type of work. With 46 (9.8%) of production workers that developed NIHL and their area of work played a significant role.

It is believed that noises that have a sharp peak present a greater hazard to hearing than noises of equal energy levels that have a continuous distribution of energy across a broad frequency range [25] This would have influenced the higher NIHL prevalence for maintenance in comparison with production work.

There are many factors that affect the degree and extent of hearing loss such as the intensity of the noise (sound pressure level), the type of noise, the period of exposure each day and the total work duration (years of employment) [25]

The incidence of NIHL is directly related to total exposure time. It is believed that intermittent exposures are far less damaging to the ear than continues exposures, as the rest periods between noises exposures allow the ear to recuperate. [25]

There was a significant association between age and NIHL. The mean age of the study population was 44 with the prevalence of NIHL the highest in the age group 40 – 49. This correlates with other research indicating a relationship between age and hearing loss. [25] There was no association between NIHL and age and business unit combined.

As expected from the literature review there was a highly significant association between the development of NIHL and years of service, with the prevalence the highest in the 10 – 20 years service category. The mean years of service for the study population were 15 years. Surprisingly when years of service are combined with area of work there was no correlation.

There was a significant association between severity and area of work. The prevalence in the CHEMICAL PLANT for the ≤ 5 PLH category was the highest with 23.8% Noise exposure in the CHEMICAL PLANT includes the

chillers, compressor room and the sodium hypochlorite plant where noise levels exceeds 90 dB and which are frequented by maintenance and production personnel.

Noise in the paper mill is mainly steady noise produced by fans, motors, flow of water and product inside equipment, pressurised flow of liquor in stock lines, high pressure transfer of steam through the digesters, scrubber fans and motors. Impact noise producing activities at the workshops include hammering, angle grinding, and use of impact wrenches, pneumatic chippers and drills. [16]

In this paper mill the majority of workers are however not continuously for 8 hours exposed to noise. Operators control the paper making process from dedicated control rooms and may work near noisy machines during routine inspections, shut downs, trouble shooting or other routine activities. Time spent in noisy areas is approximately 60 - 70% of each shift.

This study has confirmed the findings of others that noise exposure is a significant hazard in industry and an effective noise control programme is the only way to reduce the risk of NIHL.

In conclusion, the prevalence of NIHL was 21 % despite the hearing conservation programme that is in place. This is supported by other research such as NIOSH, Bergstrom and Nystrom who reported that employees continue to develop NIHL in spite of occupational hearing conservation programmes. Noise seems to be an increasing hazard to hearing with present health promotion initiatives insufficient. [4, 20]

The majority of workers diagnosed with NIHL were categorized in the ≤ 5 PLH category (16.7%).

RECOMMENDATIONS

An effective hearing conservation programme should include:

The relevant line manager should be informed of all noise survey results and recommendations made concerning noise reduction at source and the feasibility of implementation should be investigated. Although primary prevention through engineering controls is the best way of reducing exposure it is not always possible. [28]

If engineering control measures are found to be impracticable the Occupational Hygienist should advice line management concerning suitable hearing protective devices. Hearing protective devices must be provided to employees at no personal cost and must be selected to provide adequate attenuation based on noise exposure, noise reduction ratio and suitability for each individual i.e. disposable earplug, muffs or pre-moulded ear plugs. It should also comply with the specifications as per SANS 1451. The best HPD for a given situation is the one that is consistently and properly worn by the employee [26]

A very important part of an effective strategy is awareness to ensure that individuals exposed to noise are aware of the hazard and the impact it can have on their hearing, employment prospects, and in their social and family relationships. [28]

An appreciation of the negative effects that noise can have should encourage employees to participate in the hearing conservation programme and actively protect themselves from developing NIHL [28]

This is statutory training and attendance on an annual basis should be compulsory. However not all workers are attending as line management are not always committed to protect the health of their workers or finds it difficult to release workers to attend.

The objectives of employee education with regard to the noise hazard should be:

i. Promote a comprehensive understanding of the nature, the cause and the consequences of NIHL
ii. Motivate employees to take steps towards preventing loss of their own hearing
iii. Promote positive employee attitudes towards hearing protection devices (HPDs) and encourage effective utilisation, by explaining how HPDs function and by demonstrating their enhancement of communication in noise
iv. Ensure employees ability to effectively utilise HPDs, by demonstrating their proper use and care and developing employee's competence through supervised, hands on training in the fitting of individually selected HPDs
v. Training regarding the use and maintenance of HPDs should be provided at the time the HPDS is issued, after recording a NIHL incident and annually thereafter. [27, 29]

Ongoing education regarding hearing conservation should be implemented and can include toolbox talks, health briefs, and discussions at health and safety meetings as well as occupational hygiene awareness campaigns in the workplace.

In this pulp and paper mill the company has implemented a behavioural based safety (BBS) programme, where trained observers observe worker behaviour as either safe or unsafe. It is recommended that the BBS programme is utilized to ensure compliance and promote the correct use of HPDs.

NIHL should be recorded as a work related incident and accordingly investigated: Exposure to noise and the suitability of the HPDs should be re-assessed with the employee re-trained in the use and maintenance of HPDs.

The line manager should be informed of the results of the incident investigation and a copy of the incident report should be filed in the respective employees occupational health file for future reference. [29]

Medical surveillance results should be fed back into the risk management programme and be used to evaluate the effectiveness of the hearing conservation programme. The hearing conservation programme should be evaluated through a database analysis. By analyzing a database of workers audiometric test records, hearing trends for different groups can be examined, or individuals can be compared with the reference group. [26]

Workers in a particular noisy area with increased hearing loss, might be an indication that different HPDs or noise reduction at source initiatives are needed. [26]

If a worker shows a significant threshold shift and there are no shifts for other workers in the same area, it might be an indication that the HPD is used incorrectly or that the worker is exposed to excess noise off the job. [26]

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6. ANNEXURE

Table 7: GENDER DISTRIBUTION IN RELATION TO AREA OF WORK

Business Unit/Area of work	n	Gender	
		Male	Female
Wood yard	78	77 (98.7)	1 (1.3)
Chemical plant	70	70	0
Power and Recovery	72	72	0
Pulp mill	68	67 (98.5)	1 (1.5)
Paper mill	91	91	0
Automation	49	49	0
Mechanical	68	68	0
Technical	45	44 (97.8)	1 (2.2)
N	541	538 (99.5)	3 (0.5)

Table 8: RE-DEPLOYMENT OF WORKERS IN RELATION TO AREA

Business Unit	n	Re-deployed	
		Yes	No
Wood yard	78	12 (15.4)	66 (84.6)
Chemical plant	70	7 (10.0)	63 (90.0)
Power and Recovery	72	29 (40.3)	43 (59.7)
Pulp mill	68	8 (11.8)	60 (88.2)
Paper mill	91	11 (12.1)	80 (87.9)
Automation	49	1 (2.0)	48 (98.0)
Mechanical	68	0 (0.0)	68 (100.00)
Technical	45	7 (15.6)	38 (84.4)
N	541	75 (13.9)	466 (86.1)

X^2=60.374

df =7

P-value=0.00

Table 9: YEARS OF SERVICE IN RELATION TO BUSINESS UNIT

Business unit	n	Years of service			Mean years of service
		<10	10 - 20	>20	
Wood yard	78	12 (15.4)	39 (50.0)	27 (34.6)	15.6
Chemical plant	70	15 (21.4)	25 (35.7)	30 (42.9)	15.4
Power and Recovery	72	29 (40.3)	18 (25.0)	25 (34.7)	13.2
Pulp mill	68	20 (29.4)	26 (38.2)	22 (32.4)	14.2
Paper mill	91	21 (23.1)	36 (39.6)	34 (37.4)	15.8
Automation	49	14 (29.6)	20 (40.8)	15 (30.6)	15.2
Mechanical	68	18 (26.5)	31 (45.6)	19 (28.0)	14.3
Technical	45	8 (17.8)	24 (53.3)	13 (28.9)	15.1
N	541	137 (25.3)	219 (40.5)	185 (34.2)	15

X^2 =27.506

df= 14

P-value = 0.017

Table: 10: NUMBER OF WORKERS IN AGE RANGES IN RELATION TO BUSINESS UNIT

Business unit	n	Age range					Mean age
		29 and below	30-39	40-49	50-59	60 and above	
Wood yard	78	5 (6.4)	9 (11.5)	39 (50.0)	23 (29.5)	2 (2.6)	45.6
Chemical plant	70	10 (14.3)	16 (22.9)	34 (48.6)	10 (14.3)	0 (0.0)	40.9
Power and Recovery	72	12 (16.7)	22 (30.6)	27 (37.5)	7 (9.7)	4 (5.6)	39.8
Fibreline	68	11 (16.1)	19 (27.9)	28 (41.1)	10 (14.7)	0 (0.0)	39.9
Paper mill	91	11 (12.1)	17 (18.7)	42 (46.2)	19 (20.9)	2 (2.2)	42.8
Automation	49	7 (14.3)	7 (14.3)	19 (38.8)	16 (32.7)	0 (0.0)	44.3
Mechanical	68	3 (4.4)	12 (17.7	29 (42.7)	21 (30.9)	3 (4.4)	45.6
Technical	45	3 (6.7)	16 (35.6)	17 (37.8)	9 (20.0)	0 (0.0)	41.4
N	541	62 (11.5)	118 (21.8)	235 (43.4)	115 (21.3)	11 (2.03)	42.61

X^2 = 52.781

df=28

P-value =0.003

Table 11: NUMBER OF WORKERS PER TYPE OF WORK IN RELATION TO BUSINESS UNIT

Business Unit	**n**	**Type of work**	
		Maintenance	**Production**
Wood yard	78	17 (21.8)	61 (78.2)
Chemical plant	70	13 (18.6)	57 81.4)
Power and Recovery	72	21 (29.2)	51 (70.8)
Pulp mill	68	20 (29.4)	48 (70.6)
Paper mill	91	15 (16.5)	76 (83.5)
Automation	49	49 (100.0)	0 (0.0)
Mechanical	68	51 (75.0)	17 (25.00)
Technical	45	0 (0.0)	45 (100.0)
N	541	186 (34.4)	355 (65.6)

Table 12: PREVALENCE OF NIHL IN RELATION TO AREA OF WORK

Business Unit	**n**	**NIHL**	
		YES	**NO**
Wood yard	78	19 (28.8)	47 (71.2)
Chemical plant	70	18 (28.6)	45 (71.4)
Power and Recovery	72	2 (4.7)	41 (95.3)
Pulp mill	68	9 (15.0)	51 (85.0)
Paper mill	91	18 (22.5)	62 (77.5)
Automation	49	13 (27.1)	35 (72.9)
Mechanical	68	17 (25.0)	51 (75.0)
Technical	45	2 (5.3)	36 (94.7)
N	541	98 (21.0)	368 (79.0)

X^2=20.306
df= 7
P-value = 0.005

Table 13: PREVALENCE OF NIHL IN RELATION TO TYPE OF WORK

	NIHL	**No NIHL**	**n**
Production	46 (9.8)	256 (54.9)	164
Maintenance	52 (11.2)	112 (24.0)	302
N	98 (21.0)	368 (79.0)	466 (100.0)

X^2 = 17.372

df =1

P-value = 0.00

Table 14: PREVALENCE OF NIHL IN RELATION TO TYPE OF WORK AND BUSINESS UNIT

Business Unit	**n**	**NIHL**		**No NIHL**	
		Maintenance	**Production**	**Maintenance**	**Production**
Wood yard	66	7 (10.6)	12 (18.2)	6 (9.1)	41 (62.1)
Chemical plant	63	5 (7.9)	13 (20.6)	7 (11.1)	38 (57.1)
Power and Recovery	43	1 (2.3)	1 (2.3)	15 (34.9)	26 (60.5)
Pulp mill	60	7 (11.7)	2 (3.3)	9 (15.0)	42 (70.0)
Paper mill	80	3 (3.8)	15 (18.8)	5 (6.3)	57 (71.3)
Automation	48	13 (27.1)	0 (0.0)	35 (72.9)	0 (0.0)
Mechanical	68	16 (23.5)	1 (1.5)	35 (51.5)	16 (23.5)
Technical	38	0 (0.0)	2 (5.3)	0 (0.0)	36 (94.7)
N	466	**52 (11.2)**	**46 (9.8)**	112 (24.0)	256 (54.9)

Maintenance:
$X^2 = 9.953$
df = 6
P-value = 0.12

Production:
$X^2 = 18.906$
df=6
P-value = 0.004

Table 15:PREVALENCE OF NIHL IN RELATION TO AGE AND BUSINESS UNIT

Business Unit	**n**	**Age Range**									
		29 and below		**30 - 39**		**40 - 49**		**50 - 59**		**60 and above**	
		NIHL	**No NIHL**	**NIHL**	**No NIHL**	**NIHL**	**No NIHL**	**NIHL**	**No NIHL**	**NIHL**	**No NIHL**
Wood yard	66	2 (3.0)	2 (3.0)	1 (2.0)	6 (9.0)	7 (11.0)	26 (39.0)	9 (14.0)	11 (17.0)	0 (0.0)	2 (3.0)
Chemical plant	63	0 (0.0)	10 (16.0)	3 (5.0)	11 (17.0)	10 (13.0)	19 (30.0)	5 (8.0)	5 (8.0)	0 (0.0)	0 (0.0)
Power and Recovery	43	0 (0.0)	9 (21.0)	1 (2.0)	14 (33.0)	0 (0.0)	17 (40.0)	1 (2.0)	1 (2.0)	0 (0.0)	0 (0.0)
Pulp mill	60	1 (2.0)	9 (15.0)	2 (3.0)	13 (22.0)	4 (7.0)	21 (35.0)	2 (3.0)	8 (13.0)	0 (0.0)	0 (0.0)
Paper mill	80	0 (0.0)	8 (10.0)	2 (3.0)	12 (15.0)	10 (13.0)	27 (34.0)	5 (6.0)	14 (18.0)	1 (1.0)	1 (1.0)
Automation	48	0 (0.0)	7 (15.0)	0 (0.0)	7 (15.0)	4 (8.0)	15 (31.0)	9 (19.0)	6 (13.0)	0 (0.0)	0 (0.0)
Mechanical	68	0 (0.0)	3 (4.0)	2 (3.0)	10 (15.0)	8 (12.0)	21 (31.0)	7 (10.0)	14 (21.0)	0 (0.0)	3 (4.0)
Technical	38	0 (0.0)	3 (8.0)	0 (0.0)	12 (32.0)	1 (3.0)	13 (34.0)	1 (3.0)	8 (21.0)	0 (0.0)	0 (0.0)
N	466	**3 (0.6)**	51 (11.0)	**11 (2.0)**	85 (18.0)	**44 (9.0)**	159 (34.0)	**39 (8.0)**	67 (14.0)	**1 (0.2)**	6 (1.2)
		X^2 = 17.788 df = 7 P-value = 0.13		X^2 = 4.708 df = 7 p-value = 0.696		X^2 = 10.952 df = 7 P-value = 0.141		X^2 = 9.723 df = 7 P-value = 0.205		X^2 = 2.917 df = 2 P-value = 0.233	

Table 16: PREVALENCE OF NIHL IN RELATION TO YEARS OF SERVICE

Years of service	**NIHL**	**No NIHL**	**Total**
< 10	17 (3.6)	111 (23.8)	128
10 - 20	44 (9.4)	131 (28.1)	175
20 and above	37 (7.9)	126 (27.0)	163
	98 (21.0)	368 (79.0)	466 (100.0)

X^2 = 6.684
df =2
P-value = 0.035

Table 17: PREVALENCE OF NIHL BY YEARS OF SERVICE AND BUSINESS UNIT

Business Unit	n	Years of service					
		< 10		10 - 20		> 20	
		NIHL	No NIHL	NIHL	No NIHL	NIHL	No NIHL
Wood yard	66	2 (3.0)	9 (13.6)	12 (18.2)	20 (30.3)	5 (7.6)	18 (27.3)
Chemical plant	63	3 (4.8)	14 (22.2)	4 (6.3)	14 (22.2)	11 (17.5)	17 (27.0)
Power and Recovery	43	0 (0.0)	22 (51.2)	2 (4.7)	7 (16.3)	0 (0.0)	12 (28.0)
Pulp mill	60	4 (6.7)	14 (23.3)	3 (5.0)	18 (30.0)	2 (3.3)	19 (31.7)
Paper mill	80	1 (1.3)	17 (21.3)	9 (11.3)	20 (25.0)	8 (10.0)	25 (31.6)
Automation	48	2 (4.2)	12 (25.0)	4 (8.3)	15 (31.3)	7 (14.6)	8 (16.7)
Mechanical	68	5 (7.4)	14 (20.6)	8 (11.8)	22 (32.3)	4 (5.9)	15 (22.1)
Technical	38	0 (0.0)	9 (23.7)	2 (5.3)	15 (39.5)	0 (0.0)	12 (31.6)
N	466	**17 (3.6)**	111 (23.8)	**44 (9.4)**	131 (28.1)	**37 (7.9)**	126 (27.0)

Wood yard: $x^2 = 2.346$ df = 2 p-value = 0.309
Chemical plant: $x^2 = 2.925$ df = 2 p-value = 0.232
Power and Recovery: $x^2 = 7.924$ df = 2 p-value = 0.019
Pulp mill: $x^2 = 1.239$ df = 2 p-value = 0.538
Paper mill: $x^2 = 4.233$ df = 2 p-value = 0.120
Automation: $x^2 = 4.424$ df = 2 p-value = 0.109
Mechanical: $x^2 = 0.220$ df = 2 p-value = 0.896
Technical: $x^2 = 2.608$ df = 2 p-value = 0.271

Table 18: NIHL IN CATEGORIES OF SEVERITY IN RELATION TO BUSINESS UNIT

Business Unit	n	Category NIHL			
		No NIHL	<5 PLH	5.1 – 9.9 PLH	10 and above
Wood yard	66	47 (71.2)	13 (19.7)	4 (6.0)	2 (3.0)
Chemical plant	63	45 (71.4)	15 (23.8)	2 (3.2)	1 (1.6)
Power and Recovery	43	41 (95.3)	2 (4.7)	0 (0.0)	0 (0.0)
Pulp mill	60	51 (85.0)	9 (15.0)	0 (0.0)	0 (0.0)
Paper mill	80	62 (77.5)	18 (22.5)	0 (0.0)	0 (0.0)
Automation	48	35 (73.0)	9 (18.6)	4 (8.3)	0 (0.0)
Mechanical	68	51 (75.0)	10 (14.7)	4 (5.9)	3 (4.4)
Technical	38	36 (94.7)	2 (5.3)	0 (0.0)	0 (0.0)
N	466	368 (79.0)	**78 (16.7)**	**14 (3.0)**	**6 (1.3)**

X2 = 128.100
df = 21
P-value = 0.00

Table 19: NIHL IN CATEGORIES OF SEVERITY IN RELATION TO AGE

Age Group	n	Category NIHL			
		No NIHL	<5 PLH	5.1 – 9.9 PLH	10 and above
29 and below	**54**	44 (81.5)	10 (18.5)	0 (0.0)	0 (0.0)
30 - 39	**96**	84 (87.5)	11 (11.5)	0 (0.0)	1 (0.9)
40 - 49	**203**	155 (76.4)	35 (17.2)	9 (4.4)	4 (1.9)
50 - 59	**106**	82 (77.4)	22 (20.8)	1 (0.9)	1 (0.9)
60 and above	**7**	7 (100)	0 (0.0)	0 (0.0)	0 (0.0)
N	**466**	372 (79.8)	**78 (16.7)**	**10 (2.1)**	**6 (1.3)**

X^2 = 51.139
df = 12
P-value = 0.00

Table 20: NIHL IN RELATION TO AGE AND YEARS OF SERVICE

Years service	Age	NIHL	No NIHL	n
<10	**29 and below**	2 (4)	50 (96)	52
	30 - 39	3 (6)	46 (94)	49
	40 - 49	11 (50)	11 (50)	22
	50 - 59	1 (20)	4 (80)	5
	N	17 (13)	111 (87)	128
10 - 20	**29 and below**	1 (50)	1 (50)	2
	30 - 39	7 (15)	39 (85)	46
	40 - 49	19 (24)	61 (76)	80
	50 - 59	16 (36)	28 (64)	44
	N	44 (25)	131 (75)	175
20 and above	**29 and below**			
	30 - 39	1 (100)	0	1
	40 - 49	14 (14)	87 (86)	101
	50 - 59	22 (39)	35 (61)	57
	60 and above	0	4 (100)	4
	N	**37 (23)**	**126 (77)**	**163**

<10: $x^2 = 32.150$ df = 3 p-value = 0.00
10 – 20: $x^2 = 6.197$ df = 4 p-value = 0.185
20 and above: $x^2 = 17.286$ df = 3 p-value = 0.001

Table 21: MEAN AGE AND YEARS OF SERVICE PER CATEGORY OF SEVERITY

Category PLH	Mean Age	Mean years of service
No NIHL	40.91	15
≤ 5	44.92	16
5.1 – 5.9	50.50	18
≥ 10	56.50	19

Table 22: MEAN YEARS OF SERVICE AND AGE PER BUSINESS UNIT

Business Unit	Mean years of service	Mean Age
Automation	19	19
Chemical plant	15	15
Mechanical Engineering	14	14
Paper mill	14	14
Pulp mill	12	12
Power and Recovery	16	16
Technical	15	15
Wood yard	18	18