Noise Levels in a South African bank cash centre

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ABSTRACT

Title: Noise Levels in a South African bank cash centre

Noise induced hearing loss remains a concern within the employment sector, in spite of the preventability there of. In order to effectively prevent this debilitating disorder the risks need to be fully understood. One such area that requires investigation is the cash centres within the financial, banking industry. The aim of this research study was therefore to determine whether employees within the cash centres are exposed to noise levels that could be damaging to the auditory system and warrants the implementation of a hearing conservation programme. In order to investigate the noise levels emitted during cash management processes, the researcher obtained noise level recordings, with the use of the Cirrus CR110: A doseBadge Personal noise Dosimeter. Measurements were conducted to determine L_{ex8h} dBA minimum and maximum as well as the peak SPL levels expressed in dBC. These measurements enabled the researcher to compare the noise levels to current legislation regarding noise exposure within the work place. The results revealed a mean $L_{ex,8h}$ of 75.87 dBA (SD=6.09) during the coin processing procedures, compared to 72.91 dBA (SD=8.79) during note processing. The maximum $L_{ex,8h}$ measured was 85.8 dBA. A mean peak sound pressure level of 133.4 dBC (SD = 9.81) was obtained during coin processing, compared to 129.3 dBC (SD = 8.27) during note processing. The maximum peak sound pressure level measured was 142.5 dBC. The data reveals that the noise levels in the bank cash centres do not exceed the SA legislative guidelines, but do still pose a risk for the development of NIHL as the noise levels exceed 75 dBA. As limited information is available regarding the noise exposure within the cash centres, this study highlights the need for further investigation, improved awareness regarding the noise exposure in the cash centres and the possible implementation of hearing conservation programmes within this industry.

Key words: noise induced hearing loss, hearing conservation, occupational noise exposure, banking industry, cash centres.

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ABBREVIATIONS USED IN THE STUDY

ARHL	Age related hearing loss
CIT	Cash in transit
CCM	Cash coin machine
CRM	Cash recycling machine
CVM	Cash verification machine
dB	Decibel
dBA	Decibel A-weighted
dB C	Decibel C-weighted
dB SPL	Decibel sound pressure level
EHS	Environmental, Health and Safety
ER	Exchange Rate
HCP	Hearing conservation programme
HPD	Hearing protection device
Hz	Hertz
ICMS	Integrated cash management system
kHz	Kilohertz
L_{eq}	Equivalent steady sound level
$L_{AedB(A)}$	Sound exposure level
$L_{ex, 8h\ dBA}$	Daily noise exposure level (based on an 8 hour working day)
NIHL	Noise induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
NITTS	Noise induced temporary threshold shift
NIPTS	Noise induced permanent threshold shift
OHSA	Occupational Health and Safety Act
REL	Recommended exposure limit
PEL	Permissible exposure limit
SANS	South African National Standards
SARB	South African Reserve Bank
SEL	Sound exposure level
SPL	Sound pressure level
TWA	Time weighted average
$(L_{Ar,T})_{av}$	Average noise rating level

CHAPTER ONE: INTRODUCTION

1.1. Introduction

"It's a noisy world, and hearing damage from loud sounds affects millions of people. Noise induced hearing loss (NIHL) and associated disorders of tinnitus and hyperacusis are irreversible. This is a tragedy, considering that these often debilitating conditions are preventable. The keys to prevention are in understanding the risks and consistently acting to minimise the risks" (Niquette, 2012, p.2)

Exposure to excessive noise is widespread and has been increasing over decades, especially in developing countries (World Health Organisation (WHO), 1997). In Africa, excessive noise exposure levels are prevalent in the formal sector e.g. mining (Edwards & Kritzinger, 2012) and paper milling (Viljoen, 2007) and informal occupational sector (e.g. vehicle repair, metal working) as well as the non–occupational sector (e.g. the urban environment, leisure activities) (WHO, 1997). The WHO estimates that 18% of adult onset hearing loss in various countries in Africa, including South Africa, could possibly be contributed to NIHL in the workplace (Nelson, Nelson, Concha-Barrientos & Fingerhut, 2005). Most of these countries do not have effective hearing conservation programmes (HCP) in place (WHO, 1997).

Mining is an occupational sector that has been identified as having a heavy burden of NIHL based on the WHO GBD (Nelson et al., 2005). It has long been known that employees working in the mining sector are exposed to excessive noise levels and hearing conservation programmes have been initiated by the Chamber of Mines since 1988 (Strauss, 2012). A study investigating the profile of noise exposure in South African mines found that noise levels in the industry range from 63.9 dBA to 113.5 dBA, and approximately 73.2 % of the employees in the industry are exposed to noise levels exceeding the permissible exposure level of 85 dBA (Edwards, Dekker & Frans, 2011).

In 2006 the mining sector employed 5.1% of all workers in the non-agricultural formal sectors of the economy, thus contributing extensively to the country's gross domestic product (GDP) (Strauss, 2012). South Africa's economy has gradually undergone a change and greater focus is now placed on sectors such as technology and financial services. In 2013 the finance, real estate, and business services contributed 21.5% to South Africa's GDP, whereas mining and quarrying only contributed 4.9% (Media Club South Africa, n.d.).

Although the card payment market is growing significantly in South Africa, the majority of South Africans still typically use cash in payment and other transactions (Fourier, 2008). A FinScope study released in 2007 indicated that 91% of groceries, 80 % of clothing and 21% of large appliances were still being bought cash in the South African market. This has had a significant influence on the ability of the banking sector to ensure that sufficient cash remains in circulation in the South African market. In 2009 they indicated that 98% of the banking community in South Africa mainly use the bank for cash withdrawals.

The processing, storage, and recycling of cash back into the economic market is done by cash centres. Cash centres consequently play an integral part in the cash supply chain within the banking industry (Fourier, 2008). Little is known, however, of the employment conditions within the cash centres with regard to noise emitted by the cash processing machines within these centres. Occupational health and safety regulations are followed within the cash centres, to ensure safe working environments for the employees. The South African Occupational Health and Safety act (1993) states that the employer has the responsibility to ensure, as far as it is reasonable, that the employee has a safe working environment, free from risk. Should risks be present, the employer should take all steps possible to reduce the hazardous effect of such risks, as every South African has the fundamental right to work in a safe environment (Mothiba, 2010). The employees further have the right to know about the risks associated with the employment and to be informed on how to reduce those risks (Mothiba, 2010). To follow the guidelines set out by the Occupational Health and Safety act (1993) it is therefore necessary to investigate all environmental aspects within a workplace, including noise exposure levels.

1.2. Background: Motivation for the study

Researchers (Edwards, 2008; Feuerstein, 2002) agree that exposing the human ear to excessive sound levels will result in sensorineural hearing loss or, more specifically, noise induced hearing loss (NIHL). NIHL is an irreversible sensorineural hearing loss caused by repeated exposure to loud noise for many years (Hong, Kerr, Poling & Dhar, 2013). NIHL is one of the most prevalent causes of occupational health problems, but it is also one of the most preventable (Hong et al*.,* 2013). The impact of NIHL is not confined to difficulties in hearing. It impacts an individual's health, safety, and job performance. Eventually quality of life both at work and outside of the workplace will be affected as NIHL's disruption of an individual's communication ability has a negative influence on social integration as well as self-esteem (Edwards, 2009; Hong et al., 2013). For some individuals these difficulties lead to adverse effects such as depression, fear, and embarrassment.

Individuals living with a disability such as hearing loss are the most marginalised and vulnerable groups within a society and the consequent public impact could thus be high. Disadvantages and difficulties will be present irrespective of the individual's socio-economic status, with those in less advantaged communities being affected to a greater extent as they have fewer resources to overcome the obstacles (Le Prell, Henderson, Fay & Popper, 2012). NIHL is viewed as a global health problem and an economic burden. This burden of hearing loss is estimated at 16% worldwide and is generally higher in less developed regions worldwide (Nelson, Nelson, Concha-Barrientos & Fingerhut, 2005).

NIHL is clearly not a new phenomenon, but since the industrial revolution with its introduction of noisy machinery, the prevalence and concern to society regarding NIHL has increased (Sataloff & Sataloff, 2006). During the 19th century many workers developed hearing loss due to excessive sound exposure at their workplace, but no efforts were made to prevent these injuries from occurring. In an attempt to prevent future incidences of NIHL the American Department of Labour appointed the Occupational Safety and Health Administration (OSHA) committee, which established the first criteria for noise levels considered to be safe. The original noise regulation became applicable to industries in 1971 and called for a permissible exposure level (PEL) of 90 dBA with a 5 dBA exchange rate (Suter, 2009). A revised regulation was issued in 1983 and again in 1998 (Suter, 2009). Since OSHA's first publication, various committees have set up regulations to protect workers in the workplace from occupational hearing loss. The most widely accepted exposure standards within the US include ISO 1999:2013, ANSI S3:44 and NIOSH 1972. These regulations determine the acceptable level of noise exposure within an occupational environment, taking into account the risk factors which influence an individual's susceptibly to developing hearing loss. These include the type of noise, the intensity of the noise, and the time the employee would be exposed to that noise (Edwards, 2009).

The International Standards Organisation (ISO) published the "ISO 1999: Assessment of Occupational Noise Exposure for Hearing Conservation Purposes" in 1971 .The standard provides a description of the noise induced permanent threshold shift for various levels of noise exposure and procedures for estimating the risk of developing hearing loss due to noise exposure. In 1990 and again in 2013 the ISO 1999 standard was updated. The 2013 version of the ISO 1999 provides a specific method for calculating the expected NIHL due to various levels and durations of noise exposure. In contrast to the first (1971) and second (1990) edition, the 2013 edition does not stipulate a specific formula for assessing the risk of impairment. It stipulates that the predicted level of hearing loss should be used to assess the impairment, based on formulae specified within each country (ISO 1999, 2013).

The American National Standards Institute published the ANSI S3.44 in 1996 (Edwards, 2009). This document, with the same name, was an adaptation of the ISO 1999:1990. In statistical terms, it provides the relationship between noise exposure and the noise induced permanent threshold shift, in people of various ages. The US-based National Institute for Occupational Safety and Health (NIOSH) published the "Criteria for a Recommended Standard: Occupational Exposure to Noise" in 1972, establishing a recommended standard to reduce the risk of hearing loss due to noise exposure (NIOSH, 1998). Their findings indicate that over a 40 year lifetime of noise exposure in the workplace, the risk of developing NIHL increases as the average daily noise levels increase. For a daily noise exposure of 80 dBA, 85 dBA and 90 dBA, the risk of developing NIHL was documented at 3 %, 16 % and 29 % respectively (NIOSH, 1998). Based on these findings, NIOSH recommended a time weighted average (TWA) exposure level of 85 dBA. These criteria were revised in 1998 with the addition of measures aimed at preventing NIHL (NIOSH, 1998).

The minimum requirements for the protection of workers across the European Union are specified by "The Control of Noise at Work Regulations (2005)", which replaced the "Noise at Work Regulations" as specified in 1986 (Maltby, 2005). The new directive introduced more stringent requirements, with the result that many industries which previously were not included under these noise regulations, would now be included.

Within South Africa, the South African National Standards on The Measurement and Assessment of Occupational Noise for Hearing Conservation Purposes (SANS, 2013), as well as the South African Occupational Health and Safety Act (Act 85 of 1993), states that the 8 hour average noise rating should not exceed 85 dBA. The Machinery and Occupational Safety Act of 1983 (Act 6 of 1983) also supports this notion. These regulations specify that exposure at or above 85 dBA is likely to result in a hearing impairment and the employee should consequently implement noise controls should this level be exceeded. The risk rating of the mean 8 hour TWA is shown in Table 1 (Edwards, 2009).

Table 1: South African classification of risk rating for noise exposure levels (Source: Edwards, 2009).

Mean TWA (dB)	Exposure rating factor and characterisation of risk
≤ 82	0: Insignificant risk
83 -85	1: Potential risk
86 – 90	2: Moderate risk
91 – 95	3: Significant risk
96 – 105	4: Unacceptable risk
> 106	5: Extreme risk

This risk rating is comparable to the Reinhold and Tint (2009) risk level rating between noise and health complaints. These authors compared the potential health complaints against five noise risk levels, based on criteria derived from the Noise

Directive 2001/10/EC (European Commission, 2003) and the Estonian occupational noise regulations (Resolution 2007a). The risk levels obtained with their comparison is slightly more conservative, as can be seen in Table 2.

Table 2: Risk level rating between noise and health complaints
(Source: Reinhold & Tint, 2009).

Risk level numerically	Risk Level	Criteria dBA	Possible health complaints
I	Tolerable risk	< 80	Slight harm and fatigue such as unpleasant feelings, mild difficulties during conversations, fatigue and psychological stress.
II	Justified risk	80 - 85	Moderate harm, such as the difficulties above, including decreased cognitive capacities, reflex muscles' stress and more pronounced difficulties during conversations.
III	Unjustified risk	85 – 87	Sever harm such as temporary impairment of hearing, disturbances in the circulatory system through the nervous system , heart disease, severe problems in communication.
IV	Inadmissible risk	87 – 95	Extreme harm such hearing loss, ultimate deafness, sleeping disturbances.
V	Intolerable risk	> 95	Rapid health impairments and excessive increase of the risk of accidents and occupational disease. These noise levels should be avoided in all cases.

Agriculture, mining, construction, manufacturing, utilities, transportation, and the military are industries where it is known that the employees will have excessive exposure to noise (Hong et al., 2013). In their study Tak and Calvert (2008) found that the prevalence of hearing loss is the highest within the railroad industry (36 %), followed by mining (34%), machinery manufacturing (26%), and construction (24%). Within these industries various steps are taken to reduce the exposure to noise and also the consequent risk of developing noise induced hearing loss. Industries such as finance, insurance, and real estate are not viewed as risk industries as the prevalence for occupational hearing loss was estimated at less than 10% of that working population (Tak & Calvert, 2008).

The banking industry falls within the finance sector and is consequently not viewed as an employment area with a high risk for developing occupational hearing loss. Although the risk of developing hearing loss is calculated at less than 10% for the finance industry, the risk still exists and further investigation in this area could be beneficial to the overall wellbeing of employees. One section of the area that warrants investigation is the South African banking industry. The banking industry within South Africa is a well-developed and well regulated industry. Based on the 2014/2015 World Economic Forum Global Competitiveness Survey, South Africa was ranked 6th out of 148 countries in the Financial Sector Development (The Banking Association South Africa, 2015). The South African banking sector is comprised of 17 locally controlled registered banks, two mutual banks, 41 foreign banks, 13 local branches of foreign banks, and 15 controlling companies (BANKSETA, 2013). The five biggest retail banking groups are Barclay's Africa, Standard Bank, First Rand, Capitec, and Nedbank. In 2013 the financial sector employed 161 000 people (BANKSETA, 2013).

This sector continues to diversify and has undergone various changes and transformations in the past 20 years, which led to improved technologies and machinery being used in various sections in this industry (Fourier, 2008). The modern mechanised operations and technologies in various industries decrease the physical occupational burden on the employee, but may expose them to other occupational burdens and risks (Shaikh, 1999). The most undesirable and unavoidable by-product of mechanised operations is the generation of high noise levels in the occupational setting (Shaikh, 1999). This change is also seen in the banking industry during cash management and cash supply operations within cash centres. While each one of the five major banks of South Africa has its own privately operated cash centre, the machinery used within these centres are equivalent. These machines are capable of counting and sorting between 36 000 and 40 000 banknotes per hour, generating various levels of noise during the different phases. Some companies specify the output noise levels of each individual machine which vary from 67 – 75 dBA output.

The five major commercial banks all make reference to the occupational health and safety guidelines. They specify that the company occupational health and safety policies are based on the Occupational Health and Safety Act No. 85 of 1993, with the aim of providing a healthy and safe working environment (SA Banking Sector, 2012). In light of this, the researcher searched for documented cases where the occupational health and safety act no. 85 (1993) was implemented in the banking industry or where noise levels were obtained within bank cash centres.

A single document was obtained where the Occupational Health and Safety act was mentioned, but implementation was not discussed. The Occupational Health and Safety guidebook (The Labour Department, July, 2007) for the banking and finance industry specifies that noise levels should be monitored within the cash industry as part of the occupational health and safety regulations. The document further acknowledges that workers involved with coin and banknote counting could be at risk for excessive noise exposure. No upper limit of exposure is provided in the document, although it states that engineering controls and personal protection should be applied when workers are exposed to excessive sound.

A single, unpublished document was obtained regarding noise levels within one of the major commercial banks of South Africa (PSM Industrial Hygiene Services, September 2012). The measurements were conducted and evaluated against the requirements of the Regulations for Noise Induced Hearing Loss (SANS 10083, 2003). A single measurement was conducted at various sites within the cash centre and it was identified that noise levels in specified areas were equal to or exceeded the noise-rating limit of 85 dBA (PSM Industrial Hygiene, 2012). Peak levels were noted to be as high as 147 dBC in one specified area. The report recommended that noise controlling measures be implemented in these specified sites and that hearing protection devices should be made available to all employees working at those sites. This report with its recommendation proves the legitimacy of concern regarding the safety of workers who experience repeated exposure with no noise control measures in place.

A third source supporting the hypothesis that individuals employed in bank cash centres could be exposed to excessive sound levels can be found in the State of

New York's request to amend the labour law by introducing a section specified to placing noise restrictions on coin and paper counting devices. The first amended request was filed on 9 January 2013 and again on 8 January 2014 (New York Assembly Bill 1138, 2014). Although the bill has not been passed, it supports the notion that individuals working in the cash centres are exposed to excessive noise levels, with limited to no preventative measures being put in place for these employees, in spite of many occupational safety regulations.

Keifer and Delaney (2002) measured the sound exposure levels of individuals working within the vault area of a casino, where coins and notes received from the casino floor are counted and sorted for redistribution, using machines similar to those used in the cash centres. The measurements were conducted with the Quest Electronics Model M-27 Noise Logging Dosimeter. They noted that none of the individuals included in the study were exposed to sound levels higher than the OSHA and NIOSH permissible exposure level of 85 dBA. Peak levels in the area also did not exceed the permissible 140 dBC, with the loudest peak of 124 dBC obtained during a coin counting procedure.

With limited research available in this field, the current study consequently aimed to obtain reliable measurements regarding the noise exposure within a specified cash centre working environment.

1.3. Terminology

Daily noise exposure level

The time-weighted average of the noise exposure levels for a normal 8 hour working day. This enables the expression of the amount of acoustic energy the listener received during an 8 hour work day (Luxon & Prasher, 2007).

Damage Risk Criteria

Specify the amount of noise workers may be exposed to, in an attempt to limit the risk of developing hearing loss (Edwards, 2008). These criteria provide the basis for the recommended noise exposure limits, based on the noise level and the time the individual is exposed to that specified noise level (Niquette, 2012). The South African

Occupational Health and Safety Act (Act 85 of 1993) states that 85 dBA is an acceptable level of exposure for an 8 hour work day. A time – intensity trade-off of 3 dB is applied. The trade-off between the noise level and exposure time is presented in table 3.

Table 3: Trade-off between noise level and exposure time

Level in dBA	85	88	90	92	94	95	100
Allowable time (hour)	8	4			1		0.25

From Table 3 it is clear that applying a 3 dB time – intensity trade-off would mean that with every 3 dB increase in the noise level, the allowable exposure time to that noise is reduced by half. This time intensity trade-off then assumes that there is equal risk at each of these intensities, so that 85 dBA exposure for 8 hours would produce the same extent of auditory damage as 94 dBA exposure for 1 hour.

Decibel

The unit used to measure the intensity of sound. The number of decibels will be ten times the logarithm to the base 10. The quantities concerned will be proportional to power (National Institute of Occupational Safety and Health, 1998).

Decibel C weighted

The dBC scale is used in situations were high noise levels need to be measured, as the scale is based on how the human ear responds to sound levels greater than 85 dB. This scale is employed to measure peak sound pressure levels during sound measurement recordings. The scale furthermore allows for the measurement of a greater number of low frequencies (Maltby, 2005).

Decibel A weighted

The dBA weighting system reflects the way the human ear responds to moderate sound pressure levels, as the ear is not equally sensitive to sound at all frequencies. It is the most commonly used weighting scale in hearing conservation programmes (Arenas & Suter, 2014; Maltby, 2005).

Dosimeter

A noise monitoring device that integrates noise exposure over time. A dosimeter can measure all the continuous as well as intermittent noise exposures a worker is exposed to during a monitor period.

Exchange Rate

The relationship between noise levels and exposure duration (Arenas & Suter, 2014). The exchange rate (ER) was previously known as the 'time-intensity trading rule', 'doubling rate' and the 'trading relation' (Ted & Madison, 2007). The ER indicates the allowable increase in the noise level when the time exposure to the noise is halved, whilst presuming the same amount of auditory damage (Ted & Madison, 2007). The 5 dBA exchange rate was developed in 1965 by the Committee on Hearing and Bioacoustics, whereas the 3 dBA exchange rate was only developed, with Burns and Robinson (1970) confirming the credibility there of (Ted & Madison, 2007).

Hearing Conservation

The implementation of hearing conservation processes and control of noise through engineering methods in order to prevent or minimize noise-induced hearing loss (South African Speech Language and Hearing Association, 2011).

Hearing Conservation Programme

A programme aimed at preventing noise induced hearing loss involving the implementation of aspects such as the assessment of the noise exposure in all workers, reducing the 8 hours noise rating level where it exceeds the acceptable limits, and consequent medical surveillance for employees working in such workplaces (SASHLA, 2011).

L_{eq}

Indicates the steady state sound energy of a noise, where the noise energy is averaged over time. Since noise within a working environment is a complex signal and changes over time, the noise level needs to be averaged over time (Worksafe

BC, 2007). Figure 1 provides a graphic representation of how the signal is averaged over time.

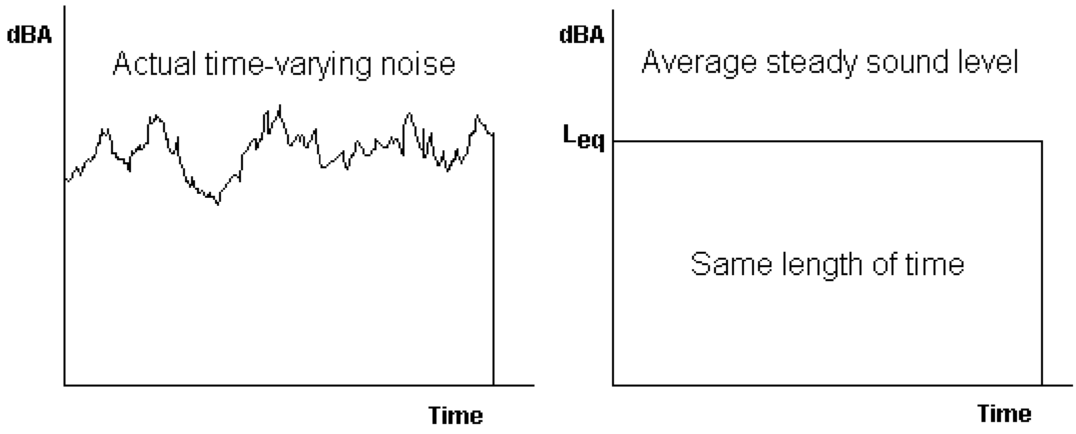

Figure 1: Representation of L_{eq} over time

$L_{EX\ 8\ hours}$

The sound level energy averaged over 8 hours, which represents the daily noise exposure dose over a typical working shift (Worksafe BC, 2007). The L_{ex} of a typical 8 hours work shift is usually greater than the measured L_{eq}, but will be less than the L_{eq} when measured for less than 8 hours (Worksafe BC, 2007). This relationship is represented in Figure 2.

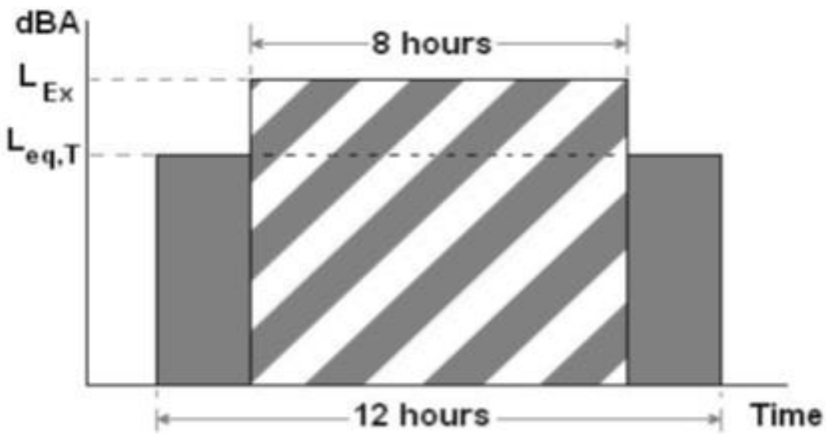

Figure 2: Comparison of the L_{eq} and the L_{ex} over time

Noise

Any undesired or unwanted sound (NIOSH, 1998).

Noise induced hearing loss

An impairment of hearing, resulting from exposure to excessive noise that manifests over a number of years and results in a bilateral and mostly symmetrical sensorineural hearing impairment (Edwards, 2009).

Occupational hearing loss

An impairment of hearing, resulting from excessive noise exposure at the individual's occupation or place of work (Sataloff & Sataloff, 2006).

Permissible exposure limit

The commonly accepted 8 hour average A-weighted sound pressure level (Arenas & Suter, 2014).

Sound exposure level

The A-weighted sound pressure level, which over 1 second contains the same amount of A-weighted energy as the single event. This enables the simple comparison of different noise events as the energy content for each is over 1 second, irrespective of the duration of the original noise event (Luxon & Prasher, 2007).

Time weighted average

The averaging of different exposure levels during an exposure period. With reference to noise, given the 85 dBA exposure limited and a 3 dB exchange rate, the TWA would be calculated as follow:

$$TWA = 10.0 \times Log(D/100) + 85$$

D indicates the dose (NIOSH, 1998).

1.4. Outline of chapters

Chapter 1: The background related to the study and the reasons for conducting the study are presented. Terminology used in the study is defined and the chapters of the study are outlined.

Chapter 2: This chapter provides a critical review of the auditory and non-auditory effects of excessive noise exposure, individual susceptibility to noise induced hearing loss, and legislation related to noise exposure within the workplace. The chapter also provides an overview of the South African banking industry and the cash management processes within the cash centres.

Chapter 3: The main aim and sub-aims of the study are formulated with a view to addressing the research challenge presented in Chapter One. The delineation of the study methodology follows, including the description of the research design, the research sample, data collection methods and instruments, and the data analysis procedures.

Chapter 4: This chapter comprises the results of the statistical analysis of the data collected with the use of personal dosebadges. The results are presented in accordance with the sub-aims of the study presented in Chapter Three.

Chapter 5: The results of the investigation are discussed and evaluated against previous studies and literature as presented in Chapter Two of the study. The discussion is structured around the sub-aims of the study and the results are compared to legislation related to occupational noise exposure.

Chapter 6: This chapter presents the conclusions drawn from the results with regard to clinical effectiveness and efficiency. The clinical implications of the study are examined, the limitations of the study are discussed and recommendations for future research in the same topic are presented.

1.5. Conclusion

Prolonged exposure to noise leads to NIHL with additional auditory and non-auditory complications such as tinnitus and poor perception abilities (Sliwinska-Kowalska &

Davis, 2012). Noise can be defined as unwanted sound that has the ability to interfere with communication and cause damage to the auditory system (NIOSH,1998). Noise is prevalent in various working industries and consequently legislation has been developed in an attempt to protect employees from excessive noise levels in the workplace. In spite of these regulations and improved awareness related to NIHL, it still remains a problem (Sliwinska-Kowalska & Davis, 2012).

Within South Africa, the South African National Standards on The Measurement and Assessment of Occupational Noise for Hearing Conservation Purposes (SANS 10083, 2013), the South African Occupational Health and Safety Act (Act 85 of 1993), and the Machinery and Occupational Safety Act of 1983 (Act 6 of 1983) specify that 8 hour average noise rating should not exceed 85 dBA, as noise levels above this specified level would lead to NIHL. Limited information is available regarding the need for the application of these regulations within the finance industry, specifically in cash centres. It is therefore important to determine whether the cash centres, with the use of noisy cash management machines, are a high risk area for NIHL.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

Millions of people are subjected daily to potentially dangerous noise levels, with a considerable number of these individuals suffering from permanent noise related hearing loss (Arenas & Suter, 2014). The purpose of this chapter is to review the field of knowledge related to NIHL, occupational hearing loss, and the legislation available to protect workers against work related injuries such as occupational hearing loss. The auditory and non-auditory effects of noise will be investigated, to postulate how these effects could influence the employees working within the cash centres. The influence of different types of noise on the auditory system will be investigated, and related to the type of noise exposure within the cash centres. Finally this chapter will investigate the regulations related to hearing conservation programmes within the South African working environment.

2.2. Prevalence of noise induced hearing loss

Estimates of the prevalence of NIHL vary widely. These differences can be attributed to the difficulties in distinguishing NIHL from age related hearing loss, variation in the size of the population exposed to excessive noise levels, and the lack of a uniform definition of NIHL (Le Prell et al., 2012). To investigate the public health impact of NIHL, the prevalence in a given population as well as the severity of the impact on every individual needs to be considered (Le Prell et al., 2012).

Approximately one third of all reported hearing loss cases can be ascribed to noise exposure, with occupational noise exposure being the most common cause of NIHL (National Institutes of Health, 1990). In the US, 10% (22 million) of adults aged 20 – 69 years have hearing loss due to noise exposure, either in the workplace or during leisure activities (Sataloff & Sataloff, 2006). More recent data estimated that 24 % of adult hearing loss in the working population of the US, aged 18 – 65 years, can be attributed to occupational noise exposure (Tak & Calvert, 2008).

Results of the 2011 South African Census estimate that 16 % of the total population (51 770 560 people) present with some degree of sensory impairment, of which

3.5% present with some degree of hearing difficulty. This figure, however, only pertains to those involved in the census and consequently the actual number of affected individuals can be higher. Though hearing loss is a major concern, with adult onset hearing loss estimated as the second leading cause of adult disabilities (Mathers, Smith & Concha, 2000), it is often minimised or ignored.

A study commissioned by the World Health Organisation (WHO) investigated the worldwide status of occupational noise exposure and the resultant hearing loss (Nelson et al., 2005). This was done in conjunction with the WHO's on-going Global Burden of Disease project (Nelson et al., 2005). This assessment evaluated the global burden of a disease from certain risk factors, and also included NIHL. The study indicated that an estimated 16 % of the disabling hearing difficulties worldwide can be attributed to excessive noise exposure at work (Nelson et al., 2005). The researchers also noted that hearing loss is the second most common occupational health hazard. To further investigate the percentage of hearing loss attributed to occupational noise exposure, Nelson and his colleagues (2005) gave report of 16 different studies conducted in 12 different countries, all relating to occupational noise exposure. From these comparisons it was deduced that the prevalence of NIHL ranges from 7 % to 21 % in adult onset hearing loss across the countries included in the study, which incorporates areas such as Pakistan, Saudi Arabia, Singapore, South Africa, and Zambia. Various occupations with varying noise exposure levels were included in the study, with the burden being more severe in the mining sector. It furthermore indicated that an estimated 18 % of adult onset hearing loss in the Southern African countries, including South Africa, can be attributed to occupational noise exposure (Nelson et al., 2005). As mentioned previously, no published articles were found to investigate the possibility that employees within the cash centres form part of this 18 % .

2.3. Effect of excessive sound exposure

Exposure to noise has anatomical, non-auditory, and auditory effects on the individual. These aspects need to be discussed as they impact on the health and safety of workers and consequently have the potential to influence the individual's quality of life (Edwards, 2009).

2.3.1. Anatomical Effects

The peripheral hearing system consists of the outer, middle, and inner ear. Exposure to excessive noise generally does not cause damage to the outer and middle ear. Consequently, individuals with NIHL will have normal functioning middle and outer ears (Hong et al., 2013).

The inner ear is affected by exposure to high levels of noise, which causes both mechanical and metabolic changes (Heinrich & Feltens, 2006; Ferrite & Santana, 2005). Depending on the type of noise, the duration of the exposure, and the intensity of the exposure, the resultant damage will either lead to noise induced temporary threshold shift (NITTS) or permanent threshold shift (NIPTS) (Heinrich & Feltens, 2006). A level of 75 dBA can be viewed as the medical safe limit of noise exposure where no permanent damage will occur to the auditory system (Mihailovic et al., 2011; Mills & Melnick, 1974). A healthy ear exposed to sound levels of 80 dBA over a long period will develop a temporary decrease in hearing sensitivity (Chen, Dai, Sun, Lin & Juang, 2007).

NITTS is caused by intracellular metabolic and chemical changes within the outer hair cells, as well as a decrease in the stiffness of the stereocillia. This leads to a decrease in the transmission of sound energy to the hair cells which ultimately alters the hearing sensitivity (NIH Consensus Statement, 1990). The changes in hearing sensitivity related to NITTS typically recover after a period of auditory rest (Chen et al., 2007; Kujawa & Liberman, 2009). The recovery is dependent on the severity of the threshold shift, intensity of the noise, and duration of noise exposure, with the greatest recovery taking place 15 minutes after noise exposure (Chen et al., 2007). Recovery within the cochlea is limited to the stereocillia of the outer hair cells, which become fused or bent with noise exposure and are consequently no longer able to effectively transmit energy (Feuerstein, 2002; Kujawa & Liberman, 2009; Wang, Yin, Yu, Huang & Wang, 2011). The recovery period is very important as it re-establishes the barrier between the endolymph and perilymph of the inner ear. Should this not occur the degeneration of the cochlear hair cells will continue. The destruction of the hair cells within the cochlea initially occurs at the site of the hair cells responsible for high frequency hearing. As the exposure continues, it leads to the impaired transmission of both high and low frequency sounds to the brain (Daniel, 2007; Hong et al., 2013).

Changes in the basal region of the cochlea do not recover and consequently the continued exposure to excessive noise levels leads to permanent degeneration of both the presynaptic and postsynaptic elements of the inner hair cells and the spiral ganglion cells (Kujawa & Liberman, 2009). Continued noise exposure furthermore results in metabolic stress within the endolymphatic fluids of the cochlea, resulting in swelling and degeneration of the eighth cranial nerve. Recent investigations involving mice also indicate that even after post-NITTS improvement, nerve degeneration may increase and accelerate age related hearing loss (Hong et al., 2013). This is indicative of noise induced permanent threshold shift (NIPTS), which is expressed as difficulty in hearing and other associated auditory disorders such as tinnitus, hyperacusis, and reduced intelligibility of speech (Feuerstein, 2002; Kujawa & Liberman, 2009).

2.3.2. Auditory Effects

The auditory effects of noise exposure include hearing threshold shift, deterioration of speech perception, and tinnitus.

2.3.2.1. Hearing Threshold Shift

This irreversible permanent threshold shift (PTS) is audiometrically characterised by an audiogram where the higher frequencies between 3000 Hz and 6000 Hz are more severely affected compared to the adjacent frequencies (Strauss, 2012). This results in the so-called “4 kHz Dip”, where a notch is noted on the audiogram in the 4 kHz frequency region. This distinctive audiometric pattern will result when individuals are exposed to broadband noise, steady noise, or noise with an impulse component (McBride & Williams, 2001). The pattern will generally be bilateral, with the notch deepening and becoming progressively broader (extending to the 2 kHz and 8 kHz frequency region) as exposure to noise continues (Feuerstein, 2002).

NIHL can thus be distinguished from age-related hearing loss, as the pattern is different to the down-sloping pattern noted in age related hearing loss (Katz, 2002).

The noise induced threshold shift may be attributed to the vulnerability of the base of the cochlea to noise (McBride & Williams, 2001). As the exposure to noise continues the notch becomes less prominent and the audiometric configuration becomes less diagnostic (McBride & Williams, 2001).

2.3.2.2. Speech Perception

Speech sounds can be divided into two groups, vowels and consonants. Consonants, such as /k/ in kick, tend to be high frequency sounds, and are consequently 'lost' when an individual presents with a high frequency hearing loss, such as NIHL (Maltby, 2005). Individuals with NIHL will often struggle to follow a conversation, especially in unfavourable conditions, as NIHL leads to decreased sensitivity for high frequency sounds and consequently diminished discrimination of consonant sounds such as /sh/ in fish (Hong et al., 2013).

2.3.2.3. Tinnitus

Tinnitus can be defined as a sound sensation that occurs in the absence of any external auditory stimulation, and is present in approximately 10 – 15% of the general adult population (Baigi, Oden, Almid-Larsen, Barrenäs & Holgers, 2011). Tinnitus leads to annoyance but can additionally influence sleep, mood, and concentration (Feuerstein, 2002). The prevalence of tinnitus in the noise exposed population is an estimated 65%, which is twice as high as in the non-exposed population (Morris, 2006). Noise exposure has a 27% risk for increasing the perception of tinnitus, and the attributable risk of tinnitus increases to 42% when noise and stress are combined (Baigi et al., 2011). Tinnitus can also influence speech recognition, which would reduce effective communication in areas where excessive noise is present (Khameneh, 2011). This could cause annoyance and stress which in turn could increase the perception of tinnitus.

2.3.3. Non-auditory effects

Excessive noise exposure has other effects on the body unrelated to hearing. Non-auditory effects include, but are not limited to, elevated blood pressure, loss of sleep, increased heart rate, heightened skin temperatures, abnormal secretion of hormones, reduced blood count, reduced immune response, and the development of hypertension which could lead to strokes (Daniel, 2007; Khameneh, 2011; Palmer, Coggon, Syddall, Pannett & Griffin, 2001).The most common of these is an increase in blood pressure, due to the narrowing of the blood vessels (Khameneh, 2011).

Aspects related to higher brain functioning, such as concentration, thought processing, and task execution, can also be influenced by noise (Morris, 2006). This could lead to accidents or mistakes in the workplace. Excessive noise exposure is furthermore reported to reduce job performance and can cause high rates of absenteeism (Morris, 2006). The additional interference of NIHL in communication could increase a worker's listening efforts, leading to a 'domino' effect of fatigue, frustration, stress, anger, and negative self-image (Palmer et al., 2001).

2.4. Individual susceptibility to noise induced hearing loss

As discussed, NIHL is influenced by the duration and the intensity of the sound to which an individual is exposed. The vulnerability to noise related cochlear damage and consequent degree of hearing loss varies substantially between individuals. This implies that different individuals will develop different degrees of NIHL at a different rate, even when being exposed to the same noise in the same environment (Edwards 2009; Sung et al., 2013). Vulnerable individuals will experience cochlear damage related to noise below noise exposure levels classified as being dangerous to hearing (Śliwińska-Kowalska et al., 2006). They are consequently at risk of developing NIHL even below exposure levels of 85 dBA. Factors such as gender, age, smoking, cardiovascular factors, blood pressure, and factors associated with blood viscosity increase an individual's sensitivity to NIHL (Daniel 2007; Sung et al., 2013). Some of these factors will be discussed in the following section.

2.4.1. Age

Adult onset hearing loss is seen as a serious health issue, with the effect ranging from social isolation due to difficulty in speech understanding, to stigmatization and economic burdens. Difficulties in communication additionally have a negative effect on the quality of life of elderly individuals. Hearing loss is the third most common chronic condition in the elderly population, after arthritis and hypertension (Meneses-Barriviera, Melo & Marchiori, 2013).

A contentious issue when estimating the effect of noise on hearing relates to the effect of age on hearing. Many similarities and interactions exist between NIHL and age-related hearing loss (ARHL) and for this reason various authors agree that the contributing effect of ARHL must be taken into account when investigating NIHL (Cruickshanks et al., 2003; Mitchel et al., 2011). Dobie (2008) conducted a study where predictions were made regarding the burden of both NIHL and ARHL in the United States. It was estimated that 10.5 % of all hearing loss in the United States could be attributed to noise exposure. This is slightly higher than the WHO estimate of 9 % (Nelson et al., 2005).

There are various similarities between NIHL and ARHL, which makes it difficult to distinguish between these two conditions (Dobie, 2008). The first is a similar audiometric pattern which is indicative of a bilateral, sensorineural hearing loss where the high frequencies are affected more compared to the low frequencies. Secondly, the audiometric "notch" described earlier becomes less clear as ARHL starts to present, making it difficult to distinguish between the two conditions. Thirdly, additional manifestations such as otoacoustic emissions and imaging are not different between NIHL and ARHL (Dobie, 2008).

In 2003, a 5 year epidemiology study monitored the progression of hearing loss among adults aged 42 – 84. The 5-year incidence of hearing loss was 21.4 %, with a higher incidence in men (30.7 %) than in women (17 %) (Cruickshanks et al., 2003). The risk of developing hearing loss furthermore increased with an increase in age, with men still being more at risk compared to women. The researchers suggested that men probably engaged in occupations with a greater risk of noise exposure, and therefore were more likely to develop hearing loss.

A similar study, conducted in 2011, investigated the progression over 5 years in adults aged 49 years and older (Mitchell et al., 2011). They noted a progression in hearing loss of 15.7 %, with the highest progression of 21.7 % in adults aged 80 years and older. This is similar to the progression noted by Cruickshanks et al. (2003). The later study, however, found no gender difference in the progression of hearing loss.

2.4.2. Gender

In a WHO project where 16 studies and 14 WHO epidemiological sub-regions were compared, it was noted that the effects of occupational noise exposure were larger in males than in females (Nelson et al., 2005). Males have a higher susceptibility for NIHL, with NIHL reportedly affecting males at a rate of 3:1 compared to females. Meneses-Barriviera et al. (2013) also report a tendency for the prevalence to be slightly higher in men compared to women. They noted that with a history of noise exposure, men are 1.8301 times more likely to develop hearing loss compared to women. Men reportedly also account for 94% of all NIHL claims within the workplace, most likely due to the tendency of males to be employed in high risk work areas such as mining, manufacturing, and construction (Morris,2006).

2.4.3. Use of hearing protection

In spite of various publications promoting the fact that the use of hearing protection will protect the individuals hearing from loud noise, many people do not use hearing protection devices (HPD) when exposed to loud noise (Daniel, 2007). Studies have indicated that even when individuals are aware of the risks of noise exposure, they remain reluctant to use hearing protection. Reasons for not wearing HPD include discomfort, effect on communication, lack of knowledge of using the devices, and peer pressure (Arezes & Miguel, 2005; Williams, Purdy, Storey, Nakhla & Boon, 2007).

2.4.4. Smoking

Smoking is viewed as a modifiable risk factor for NIHL, while it may also cause various life threatening diseases as well as premature death (Sung et al., 2013). Various studies have explored the relationship between smoking and NIHL, with some discrepancy noted in results. Some investigators found that smokers have a higher incidence of NIHL, with a possible synergistic or additive effect between these factors (Mizoue, Miyamoto & Shimizu, 2003; Palmer, Griffin, Syddal & Coggon, 2004). Others noted no significant correlation between these two factors (Śliwińska-Kowalska et al., 2006; Starck, Toppila & Pyykko, 1999). Smoking itself is not seen as a risk for hearing loss, but through the synergistic effect of noise exposure, it increases an individual’s sensitivity to noise and accelerates NIHL (Pouryaghoub, Mehrdad & Mohammadi, 2007; Sung et al., 2013). A possible explanation for this synergistic effect could be the vascular change and consequent cochlear hypoxia resulting from both noise exposure and smoking (Pouryaghoub et al., 2007). These metabolic changes related to smoking are exacerbated in older individuals, placing older individuals in an even higher risk category (Ferrite & Santana, 2005).

A possible dose-response relationship also exists between these factors, where heavy smokers have a tendency for more pronounced cochlear damage in the lower frequency region (Sung et al., 2013). This is not confirmed, however, by the study of Mizoue et al., (2003). They investigated the combined effect of smoking and occupational noise exposure, and found that smoking placed the individual at an increased risk of developing high frequency hearing loss, instead of lower frequency damage. Although some discrepancy exists regarding the frequency region mostly affected by this synergistic relationship, studies do indicate that smoking accelerates hearing loss related to noise exposure.

2.5. Outlining the noise hazard

2.5.1. Characteristics of sounds

The effect excessive sound exposure has on an individual depends on various factors, such as the sound pressure level, spectral content, exposure duration, and the temporal pattern (Arenas & Suter, 2014).The temporal pattern of sound can vary between continuous, varying, intermittent, and impulsive. NIHL can occur from continuous, intermittent exposure to loud noise or even a single impulse exposure such as an explosion. Continuous, steady state noise is a noise that does not vary more than 5 dB and contains no impulse signals (Kidd, 2002). Hearing loss related to continuous noise is usually characterised by a bilateral, symmetrical component (NIH Consensus Statement, 1990).

Impulse noise is defined as noise consisting of single burst of energy with a duration of less than one second and peak levels 15 dB higher than the background noise (Starck, Toppila & Pyykko, 2003). It is a rapid noise, with low energy content and consequently the audibility of the sound is lower than the actual sound impulse (Starck et al., 2003). Exposure to noise with impulse components, during an eight (8) hour work shift, will produce larger hearing losses (5 – 12 dB more severe) compared to the same sound level of steady state noise (Starck et al., 2003; Ya, Xue & Zhi, 2005).

In their study, Mantysalo and Vuori (1984) compared the threshold shift noted in workers exposed to continuous and to impulse noise. Individuals exposed to impulse noise were divided into three groups based on their years of exposure. Group 1 had been exposed three to four years (mean age 24.6 years), group 2 for five to six years (mean age 28.3 years) and group 3 for seven to ten years (mean age 30.1 years). The group exposed to continuous noise had had a mean exposure of 5.42 years with a mean age of 28.3 years. A control group with no history of noise exposure nor current noise exposure was also used. Hearing thresholds were obtained in the morning before going to the job site, during lunch, and again at the end of the workday. These thresholds were compared within the groups as well as between the groups. Mantysalo and Vuori (1984) noted that irrespective of the noise characteristics, the longer the exposure to noise the higher the hearing thresholds. Prior to four years of exposure the difference in NITTS noted from continuous noise exposure compared to impulse noise exposure is not significant. They further concluded that the effect of impulse noise, after four years of exposure, is more detrimental compared to continuous noise, with 4000 Hz and 6000 Hz being the most sensitive to impulse noise exposure.

2.5.2. Damage Risk Criteria

Attempts to limit human exposure to noise are based on damage risk criteria (NIOSH, 1998). The damage risk criteria for noise indicate the permissible noise level, which if not exceeded would result in an acceptable small change in the hearing levels over a lifetime of working exposure (NIOSH, 1998; SANS 10083:2013). Should an individual's noise exposure exceed this permissible level a sensorineural hearing loss will develop over time due to the hazardous effect of the excessive sound levels (McBride, 2004). The level of noise exposure, duration of the noise exposure, and the exposure limit are aspects taken into account when defining the damage risk criteria (Strauss, 2012). The most widely acknowledged noise exposure standards (ISO 1990:1999; ANSI S3.44; NIOSH (1972/1998)) stipulate an exposure level of 85 dBA. In the South African context, 85 dBA is also set as the acceptable 'noise rating limit' based on the South African National Standards

(SANS10083:2013). The EU Physical agents (noise) directive (Directive 2003/10/EC) states that the minimum exposure level and consequent fist action level should be 80 dBA (with a 3 dB exchange rate).

An even lower level was set in the United States in 1973 when the Environmental Protection Agency (EPA) published the “levels” document where an exposure limit of 75 dBA is recommended (EPA, 1973). According to this document, an 8-hour level of 75 dBA was suggested as the level that would protect public health and welfare with an adequate margin of safety.

2.5.3. Exchange Rate

The relationship between noise levels and the exposure duration is known as the exchange rate (Arenas & Suter, 2014). This relationship assumes that two or more sounds that differ in sound pressure level, duration, and temporal pattern can result in the same degree of permanent thresholds shift (Arenas & Suter, 2014). The exchange rate is based on the equal energy hypothesis, which assumes that an equal amount of sound energy will produce equal amounts of hearing impairment. *“The trading ratio is expressed as the number of decibels by which the sound pressure level maybe decreased or increased for a doubling or halving of the duration exposure.”* (Arenas & Suter, 2014, p.307). A number of studies support the exchange rate of 3 dB and not 5 dB.

2.5.4. Noise exposure legislation

Occupational noise legislation has been adopted in various countries with prominent differences in the PEL and exchange rate (Arena & Suter, 2014). One of the most commonly accepted and used standards it the ISO 1999 (Arenas & Suter, 2014). This standard can be applied to predict the degree of NIHL that can be expected based on the exposure level and duration. As stated previously, it does not provide specified limits for occupational noise exposure.

The National Institute for Occupational Safety and Health (NIOSH, 1998) states that the recommended exposure limit (REL) is 85 dBA over an 8 hour work day. Exposure to continuous, intermittent, or impulse noises should not exceed 140 dB. In environments where the noise consists of periods of different noise levels, the daily dose (D) should not exceed 100, based on specified formulae (NIOSH, 1998). For workers whose noise exposure equal or exceed these values an HCP should be implemented. This should include a noise exposure assessment, engineering and administrative controls, personal hearing protectors, audiometric evaluations, education, and recordkeeping.

Arenas and Suter (2014) investigated the current legislation on occupational noise in Latin America, Canada, and the United States. Within the United States, The Occupational Safety and Health Administration (OSHA) within the Department of Labour was the first agency to specify regulations regarding noise exposure in the workplace. The first regulation became applicable in 1971 and specified a PEL of 90 dBA with a 5 dB exchange rate (Arenas & Suter, 2014). This regulation was amended in 1981, with a lowering of the action level to 85 dBA and no longer 90 dBA. It was amended again in 1983, but sections (a) and (b) relating to the PEL and feasible engineering and administrative controls to lower the exposure, remained the same. For this reason the amendment of 1981 is still in effect.

Industry acceptable noise exposure limits are also specified by the US Mine Safety and Health Administration, United Stated Department of Energy, United Stated Coast Guard, United States National Aeronautics and Space Administration, and the United States Department of Defence. These industry specific regulations are summarised in Table 4.

Table 4: Industry Specific Noise Exposure Regulations in the United States

Industry	PEL	Exchange rate	Action Levels
Mine Safety and Health Administration	90 dBA	5 dB	85 dBA
Department of Energy	85 dBA	3 dB	Not specified
Coast Guard	82 dBA	Not specified	77 dBA
National Aeronautics and Space Administration	85 dBA	3 dB	82 dBA
Department of Defence	85 dBA	3 dB	Not specified

Table 5 provides a summary of the main features of the legislation for the other countries also investigated by Arenas and Suter (2014).

Table 5: Main noise legislation features in Latin America and Canada (Arenas & Suter, 2014).

Country	Legislation / Regulation /Standard *	PEL	Exchange rate	Maximum upper limit of exposure	Impulse Noise limit	Action Levels
Argentina	Law 19.587 of 1972	85 dBA	3 dB	124 dBA	140 dBC	When the PEL is exceeded
Bolivia	Standard on Occupational Noise NB 510001	85 dBA	3 dB	105 dBA (without HPD)	Not specified	TWA exceed 85 dBA for 8 hours (100% dose)
Brazil	Law 3214	85 dBA	5 dB	115 dBA (without HPD)	120 dBC	TWA exceeds 80 dBA for 8 hours (50% dose)
Canada **	Federal Regulation	87 dBA	3 dB	Not specified	No separate requirement	84 dBA
Canada	Variations per province	90 dBA Quebec 85 dBA all other provinces	5 dB NW Territories Quebec Nonavut	Not specified	140 dBC	80 dBA Manitoba Saskatchewan
Chile	Decree 594 of 1999	85 dBA	3 dB	115 dBA	140 dBC	TWA exceeds 82 dBA for 8 hours (50% dose)
Colombia	Regulation 1792 of 1990	85 dBA	5 dB	115 dBA	140 dBC	When the PEL is exceeded

Costa Rica	Institute of Technical Standards: Code INTE 31-09-16-00 of 2000	85 dBA	3 dB	115 dBA	Not addressed	82 dBA
Cuba	National Bureau of Standards: NC871 of 2011	85 dBA	3 dB	135 dBA	140 dBC	When the PEL is exceeded
Dominican Republic	Decree 522-06 of 2006	80 dBA	Not specified	140 dBA	Not addressed	When 80 dBA is exceeded
Ecuador	Decree 2393of 1986 Article55	85 dBA	5 dB	115 dBA	140 dBC	When the PEL is exceeded
Honduras	General Regulation STSS-053-04 of 2004	85 dBA	5 dB	115 dBA	140 dBC	80 dBA over 8 hour exposure
Mexico	Standard NOM-011-STPS of 2001	90 dBA	3 dB	105 dBA	Not specified	When PEL is exceeded
Nicaragua	General Law 618 of 2007	85 dBA	Not specified	Not specified	140 dBC	85 dBA over 8 hour exposure
Panama	Decree 306 ; regulation RT 44-200	85 dBA	5 dB	115 dBA	Not specified	When the PEL is exceeded
Paraguay	Decree 14390of 1992	85 dBA	5dB	115 dBA	140 dBC	Not specified
Peru	Decree 046-2001-EM of 2001	85 dBA	3 dB	100 dBA	Not specified	Not Specified

* It should be noted that in the field of occupational noise, the words *legislation, regulation*, and *standard* are often used interchangeably.

** The Canadian government issues the legislation regarding occupational noise exposure, but each of the 13 provinces can set their own limits and therefore some variation exists between the limits (Canadian Centre for Occupational Health and Safety).

It is clear that there are noticeable differences between the regulations for the different countries. The majority of the countries investigated (81 %) applies a PEL 85 dBA, with 54 % using an exchange rate of 3 dB and the remainder using 5 dB. The Canadian federal regulation is the only legislation that specifies a PEL of 87 dBA with a 3 dB exchange rate. America and Mexico use a PEL of 90 dBA, with an exchange rate of 5 dB in America and 3 dB in Mexico. All other countries investigated apply a PEL of 85 dBA. Based on their comparative analysis, Arenas and Suter (2014) noted that the application of an 85 dBA PEL with an exchange rate of 3 dB provides the best protection for noise exposed employees. It is furthermore clear that the OSHA legislation provides the least protection for all duration exposures.

The European Union Directive released in 1986 (86/188/EEC) states that an area should be demarcated as a noise zone when exposure is at or above 90 dBA. At 85 dBA hearing protection should be made available and exposed workers should be trained regarding HCP and noise risks. At 90 dBA hearing protection is required and an effective HCP should be implemented.

These values were revised and the new directive came into effect in 2006 (European Directive, 2003/10/EC). The Physical agents (noise) directive (Directive 2003/10/EC) now specifies the minimum requirements for workers exposed to noise within the European Union (Maltby, 2005). The biggest change in the new directive is lowering the action levels by 5 dB. Precautionary measures such as training the employees and making hearing protection available should now be implemented at 80 dBA. Protective measures such as entering into an HCP and mandatory use of HPD should now be implemented at 85 dBA. The new directive has also added a maximum exposure limit of 87 dBA. This means that the maximum daily exposure, taking into account the attenuation provided by HPD, may not exceed 87 dBA. This implies that the employer should take responsibility for the issuing of correct HPD and ensuring that the employees use these devices correctly.

The South African National Standards document on *The Measurement and Assessment of Occupational Noise for Hearing Conservation Purposes* (SANS 10083, 2013) states that an HCP should be enacted when an employee is exposed to noise levels which equal or exceed an 8 hour time weighted average of 85 dBA. In order to ensure safe working environments SANS states that the employer shall measure the noise levels according to the applicable SANS and where noise levels reach or exceed 85 dBA the employer shall institute noise controls. Where this is not practical the employer shall demarcate the noise areas as noise zones, issue a suitable HPD, train employees in the usage of the HPD, and limit their time of exposure.

Similarly, the South African Occupational Health and Safety Act (Act 85 of 1993) states that the 8 hour average noise rating should not exceed 85 dBA, as exposure at or above that level is likely to result in a hearing impairment. Employees exposed to these levels should be entered into an HCP programme, and also provided with and trained in the use of personal HPDs. With a 3 dB exchange rate in noise exposure levels, all employees exposed to noise levels of 90 dBA or more are mandated to always wear hearing protection within the demarcated area. OSHA further states that maximum sound exposure may not exceed 115 dBA and peak levels may not exceed 140 dBC sound pressure levels.

2.5.5. Hearing Conservation

An important aspect to remember regarding NIHL, is that it can be prevented (Feuerstein, 2002). The body of research related to NIHL demonstrates the strenuous attempt to improve the information at hand and enhance the efforts to prevent NIHL. Many individuals will be exposed to hazardous noise levels within their workplace, in spite of the fact that noise control in the workplace is legislated by various institutions. When noise levels exceed the PEL within a specified country, the legislation needs to be taken into account and the reduction of the noise levels will be the first step toward protecting the workers (Royster & Royster, 1990).The most practical and economically feasible method to reduce the noise levels is to implement engineering and/or administrative noise control measures (Royster & Royster, 1990). Although controlling the sound level is the best and most effective way to reduce occupational exposure to noise, many companies do not implement sound control solutions due to high initial costs and instead prefer to protect their workers by personal hearing protection devices (Williams et al., 2007).

In areas where the noise rating level cannot be reduced to an acceptable PEL, the area must be demarcated as a noise zone and all employees entering that zone are obliged to wear hearing protectors (SANS 10083, 2013). The use of hearing protection devices (HPD) and the monitoring of the use forms part of a hearing conservation programme (HCP). AN HCP would be implemented in these demarcated noise zones and would further include the effective education and motivation of all noise exposed employees (Franks, Stephenson & Merry 2006; Royster & Royster, 1990). All employees exposed to noise need to be aware of the components of the HCP, potential sources of noise, the auditory as well as non-auditory effects of noise exposure, and to be educated on the proper use of HPDs (SANS 10083, 2013). Education is extremely important, as the way the workers perceive the risks of noise exposure will influence their understanding of the HCP and consequent use of HPDs (Arezes & Miguel, 2005; Rundmo, 1996; Suter & Franks, 1990).

2.6. Understanding cash management

The South African Reserve Bank (SARB) is the central bank of the Republic of South Africa. The bank, as part of its various roles and responsibilities, assumes the responsibility of ensuring that the South African money, banking, and financial system as a whole meets the requirements of the community and keeps abreast of international developments (SARB, 2007/2008). Within this structure, the bank needs to ensure that the integrity and supply of currency is maintained, through on-going efforts to combat the counterfeiting of currency and ensuring that acceptable banknotes and coins are placed back in circulation. SARB is therefore required to:

- Monitor the compliance of all cash recyclers (cash centres) to ensure that the minimum standards for banknote recycling machines and procedures, as well as cash-coin machines, are met;
- Improve the processing capacity in the bank and bank cash centres;.
- Coordinate the distribution of currency within the cash value chain to ensure an adequate supply of currency.

In order to reach these aims, SARB initiated the Integrated Cash Management System (ICMS) in collaboration with commercial banks. The ICMS is designed to improve the efficiency and effectiveness of currency distribution, consequently reducing the cost of cash to the public (SARB, 2007/2008).

The interaction between SARB and the commercial banks is illustrated in Figure 3.

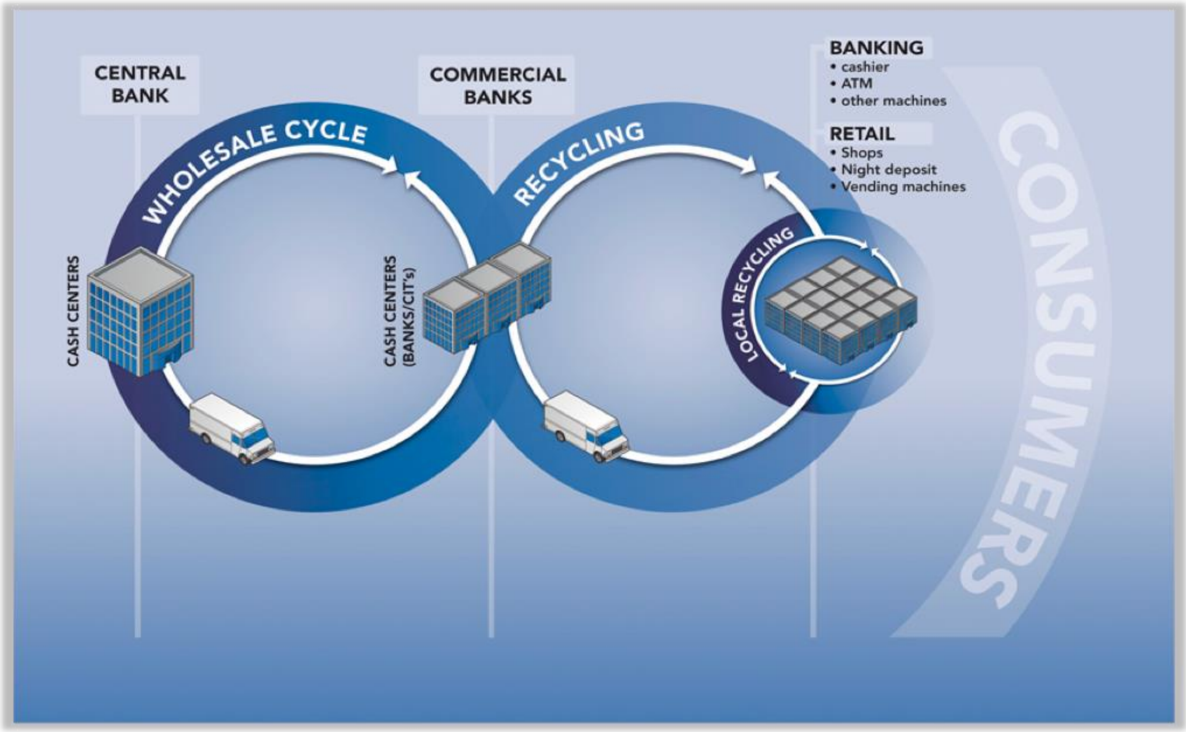

Figure 3: The Interaction between SARB and the commercial banks

The commercial banks are responsible for the verification of cash deposits and the recycling of cash, according to the SARB standards and protocols. These processes are conducted within the cash centres, with the point of entry into the cash centre being the receiving room. Here the operator will scan the received cash deposits and check them against the transfer notice from the commercial bank or the CIT Company. These cash deposits are individually sealed and identification is done according to a barcode specified by the cash centre management system.

The unsorted denominations are then manually transported to the relevant processing area, i.e. the teller area or the treasury. Within the processing area the cash deposits are counted, verified, sorted, and repacked in bundles before it is sent back into circulation. This is done with the use of cash verification machines (CVM), cash recycling machines (CRM), and cash counting machines (CCM).

A CVM is a user operated machine used to process banknotes for the reissuing of cash to a cash dispensing device such as an automatic teller machine. CVM's are capable of checking the authenticity of the banknotes, but not the fitness and physical condition of the notes.

CRM's, however, are able to check the authenticity, fitness, and physical condition of the banknotes (SARB, 2006). CRM's are consequently used to count and sort banknotes. The banknotes are sorted into "fit" and "soils". Fit banknotes go back into circulation through the cash value chain. Soils, which include banknotes not recognised and counterfeit banknotes, are returned to SARB for subsequent destruction. CCM is used to count and sachet coins.

These procedures should be done in accordance with the SARB minimum standards for recycling of cash (2006) and the Prevention of counterfeit currency act (Act 16 of 1965).

2.7. Employee Awareness

In spite of the measures and regulations set by countries, the prevalence of noise induced hearing loss continues (Bockstael, De Bruyne, Vinck & Botteldooren, 2012). The continued manifestation of noise induced hearing loss in the industry is an indication that HCP's are not effectively implemented. The failure to provide meaningful training and knowledge expansion regarding the risks of noise exposure is a key concern related to the failure of HCP's.

Risk recognition and individual risk perception are critical precursors of risk behaviour. Therefore, the manner in which workers perceive a risk will play a critical role in their understanding of risk management and consequently their own safety (Arezes & Miguel, 2008). Excessive noise levels can be viewed as an "invisible" risk, as the damage process is chronic and the influence is not immediately seen (Arezes & Miguel, 2005). Unless the noise levels are so loud that it causes physical discomfort, or produce NITTS, the short term effect of noise is not clearly noted and this creates a situation where the worker is not concerned in the short term, unless properly educated (Arezes & Miguel, 2005). Individual risk perception should thus be considered in the design and implementation of hearing conservation programmes. Arezes and Miguel (2005) also noted that many workers are not aware of the exact risk of the noise and thus view their workplace, where HPDs are required, as "not dangerous to hearing abilities".

The use of personal HPDs is the employees' best method to protect their hearing, but several studies indicate that employees still do not regularly use these devices (Arezes & Miguel, 2008, Oloqe, Akande & Olajide, 2005). Oloqe et al. (2005) noted in a study conducted in Malaysia that out of the 80% of workers who were provided with HPDs only 5% used the devices on a regular basis. In Nigeria they noted that despite the workers' awareness of the hazardous effect of high noise levels and the benefits of using HPDs, only 28% used HPDs on a regular basis. A study conducted in Sweden noted a significant relationship between the use of HPDs, a workers risk perception, and the knowledge regarding hearing protection (Sevenson, Morata, Nylen, Kerieq & Johnson, 2004). These researchers found that despite the training conducted only 20.3% of employees reported regular use of HDPs.

2.8. Summary

It is clear that an extensive body of knowledge exists regarding NIHL, occupational hearing loss, legislation, and the implementation of HCPs within various industries. Such information is lacking, however, in the financial industry, especially in bank cash centres. Concerns regarding the noise levels have been raised on the grounds of the information provided in the Occupational Health and Safety guidebook (July 2007) for the banking and finance industry and the Environmental, Health, and Safety (EHS) Guidelines (Word Bank Group, 2007). With limited information available regarding occupational noise exposure within the cash centres, there is an evident need to investigate the noise levels to determine if hazardous levels are present.

CHAPTER THREE: METHODOLOGY

3.1. Introduction

Noise in the workplace is a major cause of concern for the occupational health and safety of employees (Mihailovic et al., 2011).Taking into account the dearth of research related to noise exposure during cash management services (such as in the cash centres), this study aimed to provide quantitative data related to the noise exposure levels within the cash centres when cash management is taking place. More specifically, it aimed to ascertain whether employees in these work environments are at risk of developing occupational NIHL and consequently need to be enrolled in a HCP.

This chapter presents the objectives of the study, the research design to reach those objectives, the description of the participants, material and apparatus used to collect the data, data analysis and the ethical considerations for the study.

3.2. Research aim

The aim of this study was to establish whether the noise levels within cash centres exceed levels which warrant the implementation of a hearing conservation programme, during bank note and coin processing procedures.

3.3. Research design

The research design provides a logical structure that guides the process, which enables the researcher to answer the research question (McMillan & Schumacher, 2010). An information sheet, related to various demographic aspects was provided to employees working in the cash centres. A descriptive method was used to analyse the data and discuss the employee's demographic characteristics. A descriptive research method examines a situation as it is, without attempting to change or modify the situation (Leedy & Ormrod, 2005).This holds true for this research study as no attempt was made to change or modify the employee's working environment, as the researcher attempted to obtain information related to the current environment.

According to Kumar (2011) quantitative research designs should be structured, fixed and predetermined to ensure the accuracy of the measurements. The quantitative data was collected via personal noise dosimetry to investigate the noise levels the employees are exposed to. Noise measurements were collected throughout the working day during note and coin processing procedures, in order to investigate whether a difference exists in the noise exposure levels between these cash management processes. The quantitative research involved gathering numerical measures, which were analysed statistically in order to explain facets specified in the research question (Leedy & Ormrod, 2005).

3.4. Ethical Considerations

Ethics in health research constitutes the entities that determine the norms and values that guide a scientific reflection of a given topic (MRC, 2002). All professionals are guided by a code of ethics that evolves over the years to accommodate the change in the beliefs, values, needs and expectations of that profession (Kumar, 2011). The main intent of ethics in research is to benefit the subjects and ensure their wellbeing. Ethics or ethical behaviour can be defined as "In accordance with principles of conduct that are considered correct, especially those of a given profession or group." (Kummins, 2011, p.242). To remain within the principles of conduct, the researcher had the responsibility to ensure that the four main ethical principles of autonomy, beneficence, non-maleficence and justice were adhered to at all times (HPCSA, 2008; MRC, 2002).

- **Informed consent**

Prior to any engagement with research participants, ethical clearance compliant with the regulations of the Research and Ethics Committee of the Faculty of Humanities, was obtained (Appendix A). Once approval was obtained, informed consent documents were distributed to all employees working within the two cash centres selected for the study, as it is unethical to collect information from participants without their expressed willingness to do so (Kummins, 2011). Informed consent is a fundamental ethical consideration (Mouton, 2001). Subsequently, a cover letter of informed consent (Appendix B) explaining the aim of the study and the participant's contribution during the study was given to all employees. The letter also explained that participation was voluntary and that participants could withdraw from the study at any time, without any harm coming to them. Additional aspects such as possible benefits of participating in the study, expected results from the study and the possibility that the results would be published, was discussed with the participants on the day of the data collection. The cover letter aimed to ensure that that the participants were knowledgeable on why the research was being conducted and were able to provide voluntary informed consent (Kummins, 2011).

- **Beneficence and non-maleficence**

When conducting research it is important to ensure that no harm will come to the research participants. Harm includes "any social research that might involve such things as discomfort, anxiety, harassment, invasion of privacy, or demeaning or dehumanising procedures." (Kummins, 2011, p.245). Preventing harm, implies that all required steps should be taken to ensure that the exposure to harmful aspects would not be more during the research period, compared to the natural everyday exposure. As the research design did not involve any experimental aspects or change in the employee's natural working environment, the risk of causing harm to the participants was minimal. The establishment of accurate noise exposure levels, could benefit the participants by establishing whether they should be included in a HCP in order to protect themselves from occupational NIHL.

- **Autonomy and confidentiality**

Information obtained during the course of this study that revealed the identity of a participant or institution was treated as confidential. The informed consent document provided an area where the participant had to state their name for record keeping purposes and enable the researcher to contact the participant should the researcher note an error on the questionnaire. The participants could however choose to not complete that information, as they have the right to remain anonymous (Kummins, 2011). To ensure confidentiality, the research participant names were not used in any of the research data provided to external parties, such as the statistician. A specific numerical code was allocated to each participant and institution for data processing. In this way the names of the participants and institutions were not used in the data analysis or reporting of the data. The researcher also had to sign a non-disclosure agreement with the commercial bank involved in the study, which states that the autonomy and privacy of the commercial bank, their employees, partners and suppliers will be maintained at all times.

- **Honesty**

In order to ensure that scientific misconduct does not occur, the researcher adhered to the principle of scientific and academic professionalism (HPCSA, 2008). The researcher did not fabricate or falsify data or results presented. Where needed, the researcher acknowledged the ideas, processes, results or words of others (HPCSA, 2008; Leedy & Ormrod, 2005).

3.5. Sample

3.5.1. Sampling Method

The study population refers to all individuals who possess the characteristics a researcher is interested in and wishes to draw a conclusion from (Hicks, 2009). The two cash centres (related to the same bank) investigated during this research study was selected based on convenience sampling, due to logistical constraints pertaining to the data collection as well as security access which could be arranged at the given bank. Convenience sampling however does not enable to researcher to obtain a representative picture of the population (Leedy & Ormrod, 2005). The sample is simple a subset of the population, from which conclusions would be drawn regarding the larger population (Hicks, 2009). The sample was selected based on the principles of stratified sampling. In stratified sampling, the population can be divided into different strata and the researcher samples participants from the different strata, in accordance with the proportions of each strata (Leedy & Ormrod, 2005). The sampling design is depicted in Figure 4.

(See page 40)

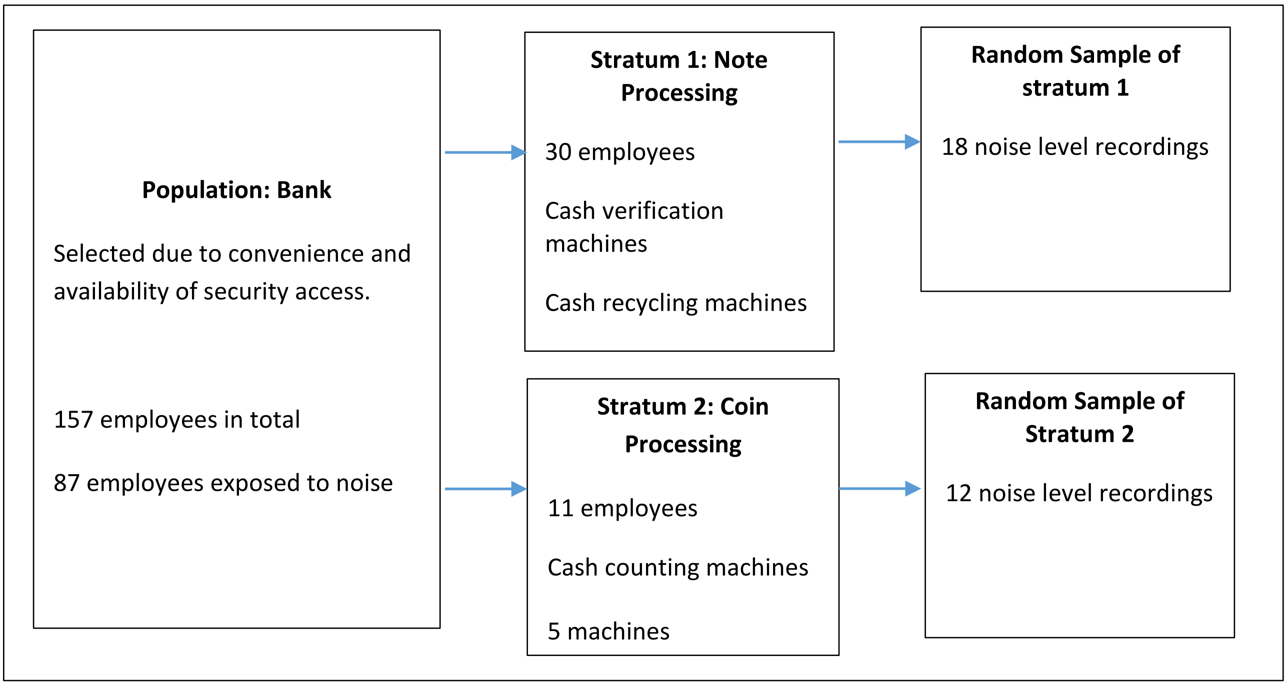

Figure 4: Stratified sampling design

3.5.2. Description of the research areas

The two identified cash centres are both operated and managed by the same financial institution. The cash centres differ from one another in terms of geographical location and size, where centre 1 is larger compared to centre 2. Both these sites consist of the same four areas where the same activities are conducted.

Table 6 provides an indication of each operational section within the cash centres, together with a brief explanation of the activity conducted in that section.

Table 6: Cash Centre operational sections and activities conducted

Operational Section	Activity Conducted
Administration	Employees employed in management and supervisory positions work within the administration section. These offices are located at a specific section and duties such as revision of banking procedures, auditing of cash exchanged and cash management errors, such as faulty ATM's are conducted here.
CIT Truck garage	The CIT trucks used for the transport of both sorted and unsorted cash are held in the CIT truck garage.
Teller Area	Employees employed in this section, manage note currencies. The bank

	notes are checked for authenticity with the CVM's. CRM's are used to count and sort the banknotes.
Treasury	Employees employed in this section, manage coins with the use CCM's. These machines count the coin values and sachet similar denominations into pre-cut coin sachets.

Due to the non-disclosure agreement between the researcher and the financial institution involved in the study, the researcher was not able to provide a floor plan of the working area. This constitutes a limitation to the study as a clear description of the research area cannot be provided.

The research population comprised of 157 people, 74 male and 83 female. The ages ranged from 21 years to 61 years with a mean age of 33 years. The categories of jobs include managerial positions, administration, treasury clerks, tellers and custodians. Individuals employed as tellers, treasury clerks and custodians are exposed to noise most often, due to their job description. They account for 87 of the employees in the total population. From these 87 employees, 52 (59.7%) of the exposed individuals provided informed consent to participate in the study. Nine of these individuals are only exposed to noise on an intermitted basis, as they are in managerial positions. They were consequently not included in the stratum of the sample. Based on their operational procedures during a work day, those included in the sample stratum fall within the broad category of bank note processors.

According to BANKSETA (2012) note processers are responsible for ensuring that bank notes are issues and disposed of, according to the regulations and policies of the South African Reserve Bank. They are further responsible for the preparation of bank notes and coins, the tidying of bank note bundles, the counting of bank notes and coins, running bank notes through the machines to check for authenticity, manual and machine checking and sorting of notes and coins for redistribution.

These individuals form part of the sample stratum that was involved in the research study. Table 7 provides a description of the research areas, by means of explaining individuals involved with notes and coin processing

Table 7: Description of the research areas

Demographic Information	Note Processing (n30)		Coin Processing (n11)	
	Frequency	Percent	Frequency	Percent
Age Group				
< 20 years	0	0	0	0
20-25 years	9	30%	0	0
26-30 years	16	53.3%	4	36.4%
31-35 years	5	16.7%	3	27.3%
36-40 years	0	0	2	18.2%
41-45 years	0	0	1	9.1%
46-50 years	0	0	0	0
51-55 years	0	0	0	0
> 56 years	0	0	1	9.1%
Gender				
Male	3	10%	5	45.5%
Female	27	90%	6	54.4%
Years of employment in current position				
< 1 year	6	20%	1	9.09%
1-3 years	19	63.3%	3	27.3%
4-6 years	5	16.7%	5	45.5%
7-9 years	0	0%	1	9.1%
> 10 years	0	0%	1	9.1%

The participant's ages ranged from 21 to over 56 years. The majority of the employees fall within the age range of 26 to 30 years, with 53.3% (n=30) involved in note processing and 36.4% (n=11) involved with coin processing. Overall the employees involved with coin processing are older, compared to those involved with note processing.

From the table a trend can be noticed, that more females are employed as note and coin processors, compared to males. 90% (n=30) of the individuals involved with note processing are female. Those involved with coin processing are slightly less, comprising 54.5% (n=11) in that employment area.

The employees working with coin processing have generally been employed in their current position, longer compared to those involved in notes processing. On average those involved with coin processing have been in the current working position for 4 – 6 years (45.5%), compared to 1 – 3 years (63.3%) for those involved in notes processing.

3.6. Research material and apparatus

3.6.1. Demographic Information Sheet

The demographic information sheet (Appendix A) was developed to obtain demographic information of the research participants. Section A of the information sheet contained information related to the age, gender, qualification, employment description and years in the current employment position. This information enabled to the researcher to thoroughly describe the research participants.

3.6.2. Dosimeter Recordings

The noise level measurements were conducted with the Cirrus CR110: A doseBadge Personal noise Dosimeter. The doseBadge recorded measurements based on the following parameters: 80 dBA criterion level, 3 dB exchange rate, no threshold, slow response.

The dosimetry measurements aimed to determine the A-weighted SPL levels expressed as L_{aeq} (dB) and L_{ex} (dB). The peak SPL levels were also obtained in dBC. The personal dosimeter was the preferred instrument for the noise measurements in this study, as it enabled the researcher to obtain noise level recordings continually over a period of time, therefore providing a more accurate estimation of the employees risk level. The average L_{ex} (dBA) provides noise exposure levels relative to a typical 8 hour working duration, which is important data as it allows for comparisons to legislation.

CR: 110A dosebadges are easy to easy to, lightweight and portable. With the use of a USB connection it was possible to download the noise level recordings onto the dosebadge computer software for analysis at a later stage.

3.7. Research methods and procedures

3.7.1. Demographic Information Sheet

Prior to the data collection phase, the researcher conducted an information session with the employees at the designated cash centres. All employees were gathered together and the researcher explained the following aspects to them; the aim of the research study, what would be expected of them should they participate in the research study, the informed consent document, the length of the data collection, the ethical guidelines that would be followed during the study and the possibility that the results would be published. Employees were given the opportunity to ask any questions related to the study. At the conclusion of this discussion, those employees who did not want to participate in the study were given the opportunity to leave the room.

The written consent form and demographic information sheet was personally provided to the remaining employees on the first day of the data collection. The employees had until the close of business on the first day of the data collection to complete the form. The researcher was available for questions throughout the day to ensure that the research participants accurately completed the form.

3.7.2. Dosimeter measurements

The doseBadge were calibrated against the SANS 60942, SANS 61672 – 1 and SANS 61672 - 2 requirements. All calibrations were done prior to each measurement to ensure that accurate measures were obtained. The serial number of the doseBadge, the calibration data along with the battery levels and setup information were stored for each measurement.

Before placing the microphone on the participant, the purpose for the measurements were clearly explained again. This was done to ensure that each participant continued with their daily work schedule and did not tamper with the equipment.

The microphone of the doseBadge was placed on the participant’s collar average of 100 – 150 mm from the side of the head (Cirrus doseBadge Manual). The measurements were conducted for several hours during the employee’s work shift. The recordings were not done for the entire work shift as morning preparations and afternoon logs had to remain confidential, even from the researcher. The average measurement time was 5 hours and 37 minutes.

Within each cash centre, the measurements were obtained in two different areas, namely the teller area and the treasury area. Within the teller area the cash management of notes takes place with CVM's and CRM's. Within the treasury area cash management of coins take place with CCM's. In both the cash centres investigated during this study, the teller area is larger compared to the treasury area. For this reason, more sound measurements were obtained within the teller area compared to the treasury area.

In each one of these specified cash management areas, the noise levels were measured on two separate occasions. These repeated measures ensured that the noise levels obtained were not due to random variation in the area or the participant. The length of the noise measurements obtained differ in the various areas, as it was dependent on the employees working schedule.

At the end of each measurement period, the recording session was stopped and the dosimeter was removed from the participant. Each dosimeter was then connected to the laptop, via the USB port, to download the sound level measurements of that recording session. The sound level measurements were stored in the dosebadge software and after the researcher checked that the recordings were downloaded correctly, the dosebadge memory was cleared to allow for space for the next recording.

3.8. Data analysis procedures

The data obtained was organised and integrated with the use of statistical analysis. Statistical analysis is concerned with summarising the numerical data, looking at the validity and reliability of the data and making generalizations from the data set obtained (Irwin et al., 2008). Descriptive statistics were used to organise and synthesise the data related to the demographics of the study sample. As stated previously, the Fisher's Exact Test was employed to determine if a significant difference exists between the studied samples within each cash centre.

DoseBadge measurements were compared with regards to mean and range for L_{ex} and peak dBC values for note and coin processing. The student's *t* test was implemented to determine if a statistically significant difference exists between the sound level measurements for the different currencies. These comparisons enabled the researcher to determine which cash management process (notes or coins) generates the highest level of noise.

3.9. Validity and Reliability

When investigating the accuracy of the results obtained during a research study, the researcher needs to objectively consider the validity and reliability of the data. The data obtained can be viewed as valid if it enabled the researcher to answer the research question (Irwin, Pannbacker & Lass, 2008). With regards to validity, two aspects, internal and external validity need to be taken into account. Internal validity refers to the extent to which the research design and data obtained will allow the researcher to draw accurate conclusions about relationships within the data (Leedy & Ormrod, 2005). External validity refers to the extent to which the results obtained during the study can be generalised to other contexts (Onwuegbuzie, 2000).

Various aspects can be seen as threats to both internal and external validity, during the different stages of a research study (Onwuegbuzie, 2000). Table 8 briefly explains what was done during the study to minimize possible interference and increase both internal and external validity

Table 8: Threats to internal and external validity

Threat	Definition	Applicability to current study	What was done to minimize the effect
		INTERNAL VALIDITY	
Instrumentation	Occurs when the scores obtained from instrumentation lack consistency (low reliability) or does not generate valid scores. Can occur in various ways: • Post intervention measures are not the same level of difficulty as pre-intervention measure	• No Effect – no intervention conducted during the research study	• No intervention required
	• Instrumentation has low test – retest reliability	• Variation in test – retest reliability. According to ANSI (S1.4 – 1983) the allowable error in measurements is between 1.6 dB and 2.3 dB for sound level meters.	• Measurements were repeated in each of the identified areas, to compensate for possible error and variation in measurements.
	• Intra – rater reliability: Scoring from one situation to the next is not consistent within the researcher	• Limited influence	• Scoring for sound measurements were based on the settings of the equipment, set up according to user manual instructions.
	• Inter – rater reliability: Scoring between data collectors is not consistent.	• Limited influence	• No research assistant or external scorer was used during the collection of the data.
Statistical Regression	Participants are selected on the basis of either extremely high or extremely low identified values	Limited influence	Non- probability convenience sampling was used to select the participants.
Mortality	Occurs when a participant selected to partake in the study withdraws from the study	Could have an influence as the participants are given free will to withdraw from the study without harm or consequence.	The research aim was fully explained, to ensure that participants understood that the research could contribute to their

			health and benefit. No participants withdrew from the study.
Behaviour bias	Participants have a strong bias favour for or against a specified aspect of the research protocol.	No effect - results not dependent on the participant's perception regarding the research topic. .	No intervention required.
Order Bias	Occur when multiple intervention are compared in one study and each research participant is exposed to each procedure.	Can occur if measurements are repeatedly conducted on the same day and same time of the month	Measurement days were randomly varied to ensure that sound level measurements were obtained on different days and different times of the month
EXTERNAL VALIDITY			
Population validity	Refers to the extent to which the findings can be generalised from the sample group towards a larger target population.	The researcher could assume that the accessible population is representative of the target population.	Measurements obtained are only generalised to the area in which the measurement were obtained and not the total population.
Ecological Validity	The extent to which the findings from a given study can be generalised across settings, conditions, variables and contexts	Will influence the study, as the data and final results are dependent on the setting and location in which they were obtained.	Researcher did not attempt to minimize this effect, as the aim of the study is focused within this specific context. This is however a limitation of the current study. As results cannot be generalised to the larger population
Temporal Validity	The extent to which research findings can be generalised across time.	Need to consider time, due to factors such as time of the day and day of the months that influences the amount of cash being counted in the cash centres.	As mentioned previously sound measurements were taken on different days of the month. The comparison between these times enables to researcher to determine if the day of the month has an influence on the sound level measurements.

Reliability is indicative of the consistency or precision of the measurements obtained during a research study (Schiavetti & Metz, 2006). Three main aspects namely stability, equivalence and internal consistency need to be taken into account during the research process to ensure that the measures obtained remain reliable. Table 9 summarizes the possible effect of these aspects and what was done during the research study to minimize this effect.

Table 9: Threats to reliability

Treat	Explanation	Applicability to current study	What was done to minimize the effect
Stability	Stability of measurements are also referred to as the test – retest reliability of the measurements.	Variation in sound levels on different days and times and different work place areas will not be taken into account if only single measurements are taken	Repeated measurements were obtained within each working unit, to ensure that the researcher accounts for changes in the sound levels.
Equivalence	Equivalence estimation is used to avoid the potential carry – over effect related to repeated measures.	Limited applicability as the measurements were not repeated with the same research participants, but only within the same area.	No intervention required
Internal Consistency	Consistency regarding the different scores on the same item.	The measurement consistency is not a concern as each dosebadge was calibrated prior to each measurement. The calibration ensured that the settings related to criterion level, response rate and exchange rate are consistent.	No intervention required

3.10. Summary

In this chapter the research design and methodology related to this study was explained. The research question and aims were explained. The ethical considerations were reported on. The data collection tools and procedures, as well as the data analysis methods were presented and explained. Lastly, aspects that could influence the validity and reliability during the study were presented.

CHAPTER 4: RESULTS

4.1. Introduction

"*The possible adverse effects of excessive noise exposure on hearing have been well-established" (Bockstael et al., 2012, p.1).*

Worldwide an estimated 16% of cases of hearing loss in adults can be attributed to noise in the working environment, with hearing loss being the second most common problem reported for occupational health hazards (Nelson et al., 2005). Seventy-five dBA is the internationally accepted noise level where no temporary or permanent damage will occur to the auditory system (Mihailovic et al., 2011). In the working environment, however, noise levels of 80 dBA and above over an 8-hour period are typically considered acceptable, although these noise levels can lead to auditory damage after many years of exposure.

The acceptable damage risk criteria vary between different countries and consequently not all employees are offered the same level of protection against hearing impairment in the workplace, as HCP's are initiated at different noise levels. To determine which employees need to be involved in an HCP it is necessary to obtain accurate noise level measurements within the working environment. The current study aimed to provide quantitative data regarding the noise levels within the specified cash centres, when cash management is taking place. In this chapter the results of the sound level recordings obtained during the different cash management procedures are presented in accordance with the aims of the study.

4.2. Sound Level Recording Times

Two cash centres from the same financial institution were selected based on convenience. Noise levels were obtained during the management of both coin and note currencies, as both these procedures cause noise emissions in the cash centre working environment. Noise level measurements were carried out in the teller area, where notes are processed, and the treasury area, where coins are processed, within each cash centre. Personal noise dosimeters known as CR:110 dosebadges were used for the dosimetry measurements, to determine the peak (dBC) level as well as the A-weighted noise levels expressed as L_{aeq} (dBA) and $L_{ex,8hr}$ (dBA). Eighteen dose measurements were obtained during note processing procedures and twelve dose measurements were obtained during coin processing procedures. The mean length of the noise level recordings was 05:45:07 hours. The maximum recording time of 06:08:24 hours was obtained during a coin processing procedure in cash centre two. The minimum recording time of 04:30:08 hours was obtained during a note processing procedure in cash centre one. Although the employees all work 8-hour shifts, the noise level recordings could not be obtained for the length of the 8-hour work shift, as the morning preparations and the afternoon cash management logs had to remain confidential from the researcher.

4.3. Noise levels for note versus coin processing

Noise emitted during note processing procedures emanates from cash verification machines (CVM) and cash recycling machines (CRM). The CVM checks the authenticity of the notes. Once the notes have been checked for authenticity, they are counted and sorted in denominations by the CRM. During coin processing procedures, the noise is emitted from cash counting machines (CCM), which count the coin value and sachet similar denominations into pre-cut coin sachets.

The results comprising the mean, standard deviation, minimum and maximum descriptive values of the individual dosimeter recordings obtained for both cash management procedures are presented in Table 10. The mean L_{ex8h} and peak dBC parameters were obtained to enable accurate comparisons with current legislation regarding occupational noise exposure and legislation relative to the 8-hour duration for the damage risk criteria.

Table 10: Sound level recordings obtained in the cash centres

NOTE PROCESSING				
Recording	**Cash Centre**	**L_{Aeq}dBA**	**$L_{ex,8h}$dBA**	**Peak dBC**
1	1	75,1	73,8	136,8
2	1	78	53,7	120,5
3	1	68,3	67,0	123,1
4	1	71,2	69,8	130,6
5	1	82,2	80,8	131,6
6	1	71,4	70,1	117,6

7	1	70,7	69,2	127,2
8	1	59,3	57,7	119,7
9	1	62,7	60,8	118,8
10	1	83,6	82,2	140,6
11	2	77,2	75,6	132,7
12	2	87,2	85,8	130,3
13	2	82	80,38	141,5
14	2	71,4	70	125,4
15	2	84,6	83,3	141,7
16	2	74,4	73,2	121,8
17	2	78,5	77,3	131,8
18	2	75	73,9	123,1
Mean		75.52	72.91	129.3
SD		7.41	8.79	8.27
MIN		59.3	53.7	117.6
MAX		87.2	85.8	141.7
COIN PROCESSING				
Recording	**Cash Centre**	**L_{Aeq}dBA**	**$L_{ex,8h}$dBA**	**Peak dBC**
1	1	76,3	75	136,7
2	1	84	66,3	114,8
3	1	83,4	77,6	141,8
4	1	77,1	71,8	142,5
5	1	83,1	81,5	142,4
6	1	85,9	84,5	141,1
7	2	66,8	65,3	115,4
8	2	79,2	77,7	138,8
9	2	72,3	70,8	127,2
10	2	83	81,4	128,7
11	2	74,4	73,3	127,8
12	2	80,1	78,9	136,1
Mean		79.17	75.87	133.4
SD		5.57	6.09	9.81
MIN		66.8	65.3	114.8
MAX		85.9	84.5	142.5

A trend can be noted from Table 10, namely that noise levels obtained during coin processing procedures are higher compared to those obtained during note processing procedures. The mean $L_{ex,8h}$ during coin processing procedures was 75.87 dBA (SD = 6.09) compared to 72.91 dBA (SD = 8.79) during note processing. The maximum $L_{ex,8h}$ of 85.8 dBA was, however, obtained during a note processing procedure and not a coin processing procedure.

The mean peak sound pressure level of 133.4 dBC (SD = 9.81) is higher during coin processing, compared to 129.3 dBC (SD = 8.27) during note processing. The maximum peak sound pressure level of 142.5 dBC was also obtained during a coin processing procedure.

Based on the risk rating level of Reinhold and Tint (2009) the employee's 8-hour noise level exposure can also be viewed in terms of the risk level of exposure. This descriptive analysis of the noise level exposure for note processing versus coin processing is presented in Table 11. The first level represents noise levels below 80 dBA for an 8-hour exposure period. Taking into account that 75 dBA is the safe limit of noise exposure for an 8-hour period (Mills & Melnick, 1974), the first risk level has been adjusted to 75 dBA – 80 dBA for the descriptive analysis, as noise exposure below that level would not be damaging to the auditory system.

Table 11: Descriptive risk rating levels for notes versus coin processing

Risk level numerically	Risk Level	Criteria dBA	Number exposed during note processing (n18)	Number exposed during coin processing (n12)
I	Tolerable risk	< 80	7 (38.89%)	7 (58.33%)
II	Justified risk	80 - 85	5 (27.78%)	3 (25%)
III	Unjustified risk	85 – 87	1 (5.55%)	None
IV	Inadmissible risk	87 – 95	None	None
V	Intolerable risk	> 95	None	None

This table reveals that, in accordance with Table 10, more employees are exposed to noise levels that can be damaging to the auditory system during coin processing procedures (83.33%) than during note processing (72.22%). The maximum exposure within the range of 85 – 87 dBA was again observed during a note processing procedure. The majority (58.33%) of the employees involved with coin processing, compared to 38.88% involved in note processing, are exposed to noise levels within the 75 dBA – 80 dBA range. Fewer individuals are exposed to the 80 – 85 dBA risk level, namely 25% during coin processing and 27.78% during note processing. This range is important to consider as it is known that a healthy ear exposed to sound levels of 80 dBA over a long period will develop a temporary decrease in hearing sensitivity (Chen, Dai, Sun, Lin & Juang, 2007). With continued exposure the temporary changes in the auditory sensitivity will not recover, resulting in permanent auditory changes. These employees are consequently at risk of developing NIHL. Taking these risk rating levels into account, 61% of the individuals (11 employees) involved with note processing are safe from auditory damage, as their L_{ex8h} exposure falls below 75 dBA. Only 41.67% (5 employees) involved with coin processing are safe from auditory damage.

Statistical analysis using an independent Student-t test was carried out to determine whether a significant difference existed between the noise exposure levels for the different cash management procedures within the cash centre. The difference in the mean noise exposure levels between note and coin processing was found to be not significant for either the $L_{ex,8h}$ dBA ($t = 0.302$) or the peak dBC ($t = 0.211$).

4.4. Summary

In this chapter the results obtained during this research study were presented. The sound level recordings obtained during note and coin processing were presented and analysed both descriptively and statistically. The results indicate a mean L_{ex8h} during coin processing procedures of 75.87 dBA (SD=6.09) compared to 72.91 dBA (SD=8.79) during note processing. The mean peak sound pressure level during coin processing was 133.4 dBC (SD = 9.81) compared to 129.3 dBC (SD = 8.27) during note processing. There is no significant difference between the mean exposure levels for either note or coin processing. In the next chapter the results will be discussed and compared to current legislation regarding occupational noise exposure.

CHAPTER 5: DISCUSSION

5.1. Introduction

Noise in the workplace can be a safety hazard in that it prevents employees from hearing warning signals, it can interfere with communication, and it can create stress (Maltby, 2005). Noise exposure regulations are therefore put in place to protect the workers by either reducing the noise level at the source or providing appropriate HPDs should it not be possible to reduce the noise level. Regulations consist of action levels and exposure limits. Actions levels are the levels at which the employer should take action to reduce the noise at the source as well as its effect on hearing (Maltby, 2005). Exposure limits are the noise values at the employee's ear, taking into account the noise reduction offered by the HPD (Maltby, 2005)

The $L_{ex,8h}$ dBA and peak dBC exposure levels need to be considered to determine which individuals need to be included in an HCP. Based on the exposure levels, specified protective measures need to be in place. The lower (first) exposure action level states that a variety of HPDs should be made available to employees who are exposed to noise, with voluntary usage. Audiometric screening should be made available to these employees and training should be provided regarding the HCP and risks of noise exposure (Vinck, 2015). The upper (second) exposure action level states that a variety of HPDs should be made available and the use of these devices should be enforced. Audiometric screening should be available for individuals exposed to noise and noisy areas should be demarcated as high risk areas. The maximum exposure limit states that no employee included in an HCP may exceed this level of exposure, irrespective of how brief the exposure may be (Vinck, 2015).

The results of the present study consists of $L_{ex,8h}$ dBA and peak dBC measurements for the different cash management procedures. These measurements allow comparison to the different noise regulations available, in order to determine which employees would be at risk for developing occupational NIHL and consequently need to be included in an HCP.

These action levels, however, differ depending on the relevant legislation, and due to the discrepancy in legislation there is limited uniformity when it comes to the implementation of HCP's worldwide. The South African Occupational Health and Safety Act (Act 85 of 1993), the Australian Occupational Health, Safety and Welfare Regulations (1995, effective 7 October 2004) as well as NIOSH (1972) state that employees exposed to a $L_{ex,8h}$ dBA of 85 dBA need to be included in an HCP and the maximum exposure limit for peak exposure is 140 dBC. OSHA (1998) permits an increased exposure level of 90 dBA with the peak dBC exposure level remaining at 140 dBC. The picture within the EU is much more conservative, with a minimum action level of 80 dBA and a peak exposure of 135 dBC. The upper exposure limit, where HPD use is mandatory, is stipulated at a $L_{ex,8h}$ dBA of 85 dBA and peak exposure of 137 dBC. The exposure limit for the $L_{ex,8h}$ dBA of 87 dBA still falls below the OSHA levels of 90 dBA.

5.2. Comparison of noise levels to legislation

The results obtained in the study were evaluated against the SA legislations (SANS 10083, 2013; Occupational Health and Safety Act (Act 85 of 1993), the EU Directive (European Directive, 2003/10/EC), NIOSH (1972), OSHA (1998) and the medical safe limit of 75 dBA (Mills & Melnick, 1974). Based on the differences in the legislation, the percentage of employees identified as at risk of developing NIHL may differ, with the obvious consequence that there is great variability when it comes to implementing HCP's in the industry.

When considering SA legislation, none of the employees involved with coin processing procedures are exposed to noise levels exceeding the acceptable $L_{ex,8h}$ of 85 dBA, with the exception of a single employee exposed to 85.8 dBA during a note processing procedure. The number of employees at risk increases when considering the peak dBC exposure levels. Three employees (16.67%) involved with note processing and four employees (33.34%) involved with coin processing are exposed to peak dBC values exceeding the acceptable limit of 140 dBC. These findings agree with the unpublished findings of PSM Industrial Hygiene (2012). They conducted noise level recordings in the same cash centre and they also found that a single employee involved in note processing had a $L_{ex,8h}$ of 85 dBA. Peak dBC values also exceeded 140 dBC for 20% of the employees in coin processing and 11.11% of the employees in note processing.

As stated previously, the regulations within the EU are more conservative with the first $L_{ex,8h}$ action level being 80 dBA and a peak exposure of 135 dBC (European Directive, 2003/10/EC). When considering these values the number of employees exceeding the safe $L_{ex,8h}$ and the peak dBC increases. During note processing procedures five employees (27.78%) would exceed the safe exposure limit and three employees (25%) involved with coin processing procedures would exceed the safe limit. The employees exceeding the safe peak dBC exposure would increase to four (22.23%) during note processing and seven (58.33%) during coin processing procedures. The trend thus remains, that more employees are at risk of exceeding the PEL taking into account their peak dBC exposures, compared to the daily $L_{ex,8h}$ exposures.

It should be taken into account that noise levels that are not loud enough to cause damage to the hearing system could lead to non- auditory side effects such as interference with communication and the employee's ability to clearly hear warning signals (Mihailovic et al., 2011). To take these aspects into account the employee noise exposure levels were compared to the SA Risk rating classification (Edwards, 2008) as well as the Reinhold and Tint (2009) risk rating. The SA risk rating (Edwards, 2008) states that employees exposed to a daily $L_{ex,8h}$ of less than 82 dBA have an insignificant risk of developing occupational NIHL. As stated previously, 75 dBA is viewed at the safe noise exposure level where no temporary or permanent auditory changes will occur (Mihailovic et al., 2011; Mills & Melnick, 1974). The first risk level is thus adjusted to 75 dBA – 82 dBA, as noise exposure below that level would not be damaging to the employees. Taking this adjustment into account four (22.22%) of the employees involved with note processing and 6 (50%) of the employees involved with coin processing have an insignificant risk of developing NIHL as their daily $L_{ex,8h}$ is within the range of 75 dBA - 82 dBA.

According to the risk rating of Reinhold and Tint (2009), fewer employees are exposed to tolerable noise levels, implying that more employees would be exposed to the next risk levels related to non - auditory side effects of noise exposure.

Employees exposed to a daily $L_{ex,8h}$ noise level of below 80 dBA are viewed as having tolerable noise exposure levels. The risk level range was again adjusted to 75 dBA – 80 dBA, as noise exposure below 75 dBA is viewed as medically safe (Mihailovic et al., 2011; Mills & Melnick, 1974). Only three employees involved with note processing (16.67%) and three involved with coin processing (25%) fall within the tolerable risk. Based on this risk rating, these employees would not experience any auditory effects, but aspects such as increased fatigue, unpleasant feelings during the working period, mild difficulties during conversations, and psychological stress would be present.

The next risk level is the Potential Risk (83 dBA – 85 dBA) for the SA Risk Rating (Edwards, 2008) and the Justified Risk (80 dBA – 85 dBA) based on the Reinhold and Tint (2009) levels. At this risk rating, the employees would experience similar difficulties as with the tolerable risk level, as well as decreased cognitive capabilities and more pronounced difficulties during communication. During note processing, 2 employees (11.11%) present with a potential risk and five (27.78%) present with a justified risk. During coin processing procedures, fewer employees would be exposed to a potential risk based on the SA Risk Rating (Edwards, 2008), with only one (8.33 %) employee at risk. Three (25%) employees meet the noise exposure criteria for a justified risk (Reinhold & Tint, 2009). At these risk levels, the noise exposure exceeds the EU Directive minimum action level of 80 dBA. This indicates that these employees should actually be included in an HCP programme, as they have a risk of damage to the auditory system. Based on SA legislation (SANS 10083, 2013; Occupational Health and Safety Act (Act 85 of 1993), NIOSH (1972) and OSHA (1998), however, these employees would not be included in a hearing conservation programme as their daily $L_{ex,8h}$ does not exceed 85 dBA.

It should be noted that the maximum $L_{ex,8h}$ dBA for both note processing (85.8 dBA) and coin processing (84.5 dBA) exceeds the recommended $L_{ex,8h}$ dBA of the EU Directive second or upper action level (European Directive, 2003/10/EC). This again confirms that based on these regulations the employees should be included in an HCP. At the second action level, the EU directive states that the employer should take measures to reduce noise exposure, in ways other than simply providing hearing protection. Engineering controls should be put in place to reduce the noise at the source. The areas where noise is likely to exceed the second action level (83 dBA) should be demarcated as a "Noise Zone" or "Hearing Protection Zone" and the use of hearing protectors in that area is mandatory, even when only passing through that area (European Directive, 2003/10/EC). This would imply that all employees employed as bank note processors, as well as those in managerial positions who only have intermittent exposure to these areas, should wear HPD when entering the note and coin processing area.

When considering the peak sound pressure dBC values, the employees exposed to sound levels exceeding the recommendations of SA legislation (SANS 10083, 2013; Occupational Health and Safety Act (Act 85 of 1993), NIOSH (1972) and OSHA (1998) are higher during coin processing procedures than during note processing procedures. During note processing procedures, three employees (16.67%) are exposed to peak sound pressure levels exceeding 140 dBC. This increases to 33.33% (4 employees) during coin processing procedures. Similar to the daily $L_{ex,8h}$ the percentage of employees at risk also increases when considering the EU Directive minimum action level of 135 dBC. Based on this directive, 22.22% (4 employees) of the employees in note processing and 58.33% (7 employees) of the employees involved with coin processing should be enrolled in an HCP.

From this data, a trend can be noted that the daily $L_{ex,8h}$ is higher during note processing procedures, whereas the peak dBC values are higher during coin processing procedures. This can possibly be attributed to the fact that there are more note processing machines situated in the same room, conceivably contributing as an auxiliary effect to the noise levels. There are fewer coin processing machines available in the treasury room, possibly meaning that the auxiliary effect of the noise levels from the different machines is less. Also, the procedure of coin processing is different from the procedure for processing notes. Note processing creates a more sustained noise as the notes are sent through the CVM and CRM feeders. The coin processing creates louder peaks, as the coins are thrown into the drop channel of the CCM and are then processed. Keifer and Delaney (2002) also noted that this practice creates increased noise levels during coin processing.

Similar to the current study, Keifer and Delaney (2002) also investigated noise levels within the workplace during cash processing operations. The investigation was conducted within the vault area of a casino where coin counting was conducted in one section and notes counted in a different section. They noted that sound level measurements during cash processing procedures were below the OSHA specified levels of 85 dBA. The noise monitoring results indicate that exposure to noise during cash management processes are below the established occupational risk criteria. This is in agreement with the results obtained in this study, as employees are not exposed to a $L_{ex,8h}$ dBA level exceeding 85 dBA.

When looking at the Environmental, Health, and Safety (EHS) Guidelines (2007) for the World Bank Group, the dosimeter recording levels obtained exceed the safe limit of exposure, namely $L_{ex,8h}$ of 70 dBA, specified in the document. The document does not specify the action required should these levels be reached, but noise controlling methods, including the use of HPDs are specified to reduce noise levels should it be required. Taking this information into account, one can deduce that an HCP where training is conducted and HPDs are supplied should be implemented. Mandatory use of the HPDs can, however, not be enforced as the noise exposure levels do not exceed 85 dBA. These actions would also agree with the latest EU directives (European Directive, 2003/10/EC) which state that precautionary measures such as training the employees and making hearing protection available should now be implemented at 80 dBA.

The implementation of an HCP entails careful planning to ensure effectiveness. Various aspects need to be considered to ensure that such a programme will be successful. Within the cash management industry, the researcher is of the opinion that the following aspects, recommended by Sataloff and Sataloff (2006), would be essential:

- <u>The HCP needs to have the support of management.</u> In the cash centre environment, the implementation of an HCP would be a new aspect to consider in the industry. If management is not on board and supporting the initiative, getting staff to follow the regulations and effectively protect their hearing would be extremely difficult.

- Supervisory personnel should also wear HPDs. They should preferable wear ear muffs to increase the visibility of the HPDs and show their compliance with the programme. This would be important in the cash centre as employees in managerial positions and administrators are exposed to the noisy environments intermittently.
- Education, promotion, and encouragement are essential. Again, this would be important in the banking industry as employees within the field have limited knowledge regarding NIHL, the potential risks of noise exposure, and health and safety regulations related to noise exposure. The Occupational Safety and Health Guidebook for the Banking and Finance Industry (2007) presents the following diagram to indicate how training could be conducted to ensure that employees have sufficient knowledge to work safely and not risk their health.

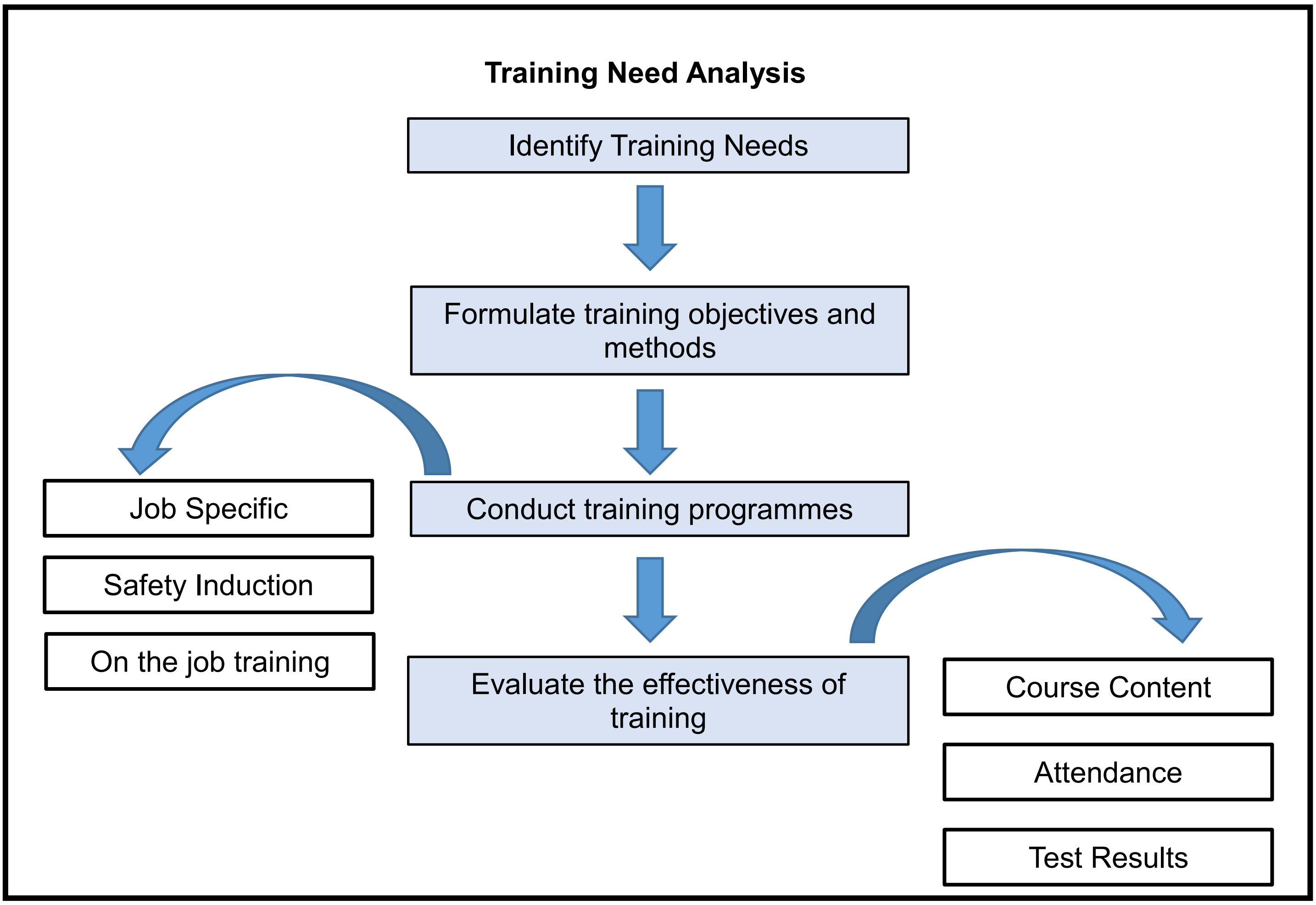

Figure 5: Training to equip employees with knowledge to work safely within the banking and finance industry

- Everyone should be included in the programme, not just the workers exposed to noise. This is a very important aspect to consider within the cash centre. As reported previously, not all workers are exposed to noise levels exceeding 80 dBA during the cash management process. The maximum $L_{ex,8h}$ and peak dBC values do, however, exceed various legislative levels viz. SANS (10083, 2013); Occupational Health and Safety Act (Act 85 of 1993); NIOSH (1972) and the EU Directive second action level (European Directive, 2003/10/EC) and consequently it can be deduced that all employees working in this environment are at risk for developing NIHL.

There are three primary means of controlling noise exposure, namely, engineering controls, administrative controls, and personal protection (Sataloff & Sataloff, 2006). The Occupational Safety and Health Guidebook for the Banking and Finance Industry (2007) states that noise levels during banking activities seldom occur at levels that cause permanent damage to the employees' hearing. The document does, however, suggest that the following three engineering controls could be implemented to ensure that noise levels do not influence concentration and efficiency during cash management procedures.

- The banknote counting machines could be housed inside a separate room in order to contain the noise emitted by the note counting machine.
- The room housing the equipment can be dressed with noise absorbing material to reduce the reverberation of the noise.
- Buffer material can be mounted in the drop channels of the coin processing machines to reduce the metal-to-metal contact and consequently reduce the noise. A similar suggestion was made by Kiefer and Delaney (2002) as they noted that most of the noise during coin processing occurred when the coins were transferred from a container to the coin processing machine via the drop channel.

5.3. Summary

Chapter 5 discussed the findings regarding the noise exposure levels in the cash centres when cash management is taking place. The noise exposure levels were compared to a variety of legislation regarding noise exposure in the workplace and the implementation of an HCP. The results of the current study yielded similar findings to those of Keifer and Delaney (2002) and PSM Industrial Hygiene (2012), indicating that the daily L_{ex8h} during cash management procedures does not exceed the SANS 10083, 2013; Occupational Health and Safety Act (Act 85 of 1993); NIOSH (1972); and OSHA (1998) recommend level of 85 dBA. On the other hand, the peak dBC values do exceed 140 dBC for some, but not all, employees.

The results furthermore indicated that when compared to the EU directive minimum action levels, the noise exposure for 27.78% of the employees in note processing and 25% in coin processing would exceed the recommended action level of 80 dBA. The peak dBC value of 135 dBC would be exceeded in the case of 22.22% of the employees during note processing and 58.33% during coin processing. Based on these findings, the chapter was concluded with a brief discussion of the possible aspects to consider when implementing an HCP within the cash centre.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

The purpose of this study was to explore whether the noise levels in bank cash centres exceeds limits that would warrant the implementation of a hearing conservation programme when cash management occurs. In order to investigate this aspect, noise levels were obtained during note and coin processing procedures in the cash centre. The results showed that elevated noise levels are present during these cash management procedures. The legislation related to the implementation of an HCP differs in different countries and consequently there is no uniform prescription regarding the implementation of an HCP based on the noise levels obtained. In this chapter it will be argued that the findings can be used to support the notion that awareness needs to be created regarding the noise levels in the banking industry, the risk of auditory damage related to these noise levels and the implementation of an HCP.

6.2. Conclusions

The noise levels obtained in the cash centres indicated that a single employee involved with note processing was exposed to a $L_{ex,8h}$ level exceeding the SANS 10083 (2013) and Occupational Health and Safety Act (Act 85 of 1993) limit of 85 dBA. When considering the peak dBC levels more employees were exposed to levels exceeding the safe limit recommended by SA legislation, with 16.67% of the employees in note processing and 33.33% of the employees in coin processing were exposed to levels exceeding a peak dBC of 140. These findings agree with the published findings of Keifer and Delaney (2002) who investigated noise levels in a casino vault when cash management took place. They also found that noise levels did not exceed the OSHA specified $L_{ex,8h}$ level of 85 dBA.

Auditory damage related to noise exposure can, however, occur at exposure levels lower than 85 dBA and for this reason the EU has decreased the acceptable noise exposure levels (European Directive, 2003/10/EC). Taking the first action level into account, 27% of the employees involved with note processing and 25% involved with coin processing would exceed the acceptable $L_{ex,8h}$ of 80 dBA. The percentage of employees exposed to unacceptable levels again increases when considering the peak dBC values, with 22.22% in note processing and 58.33% in coin processing exposed to levels exceeding the acceptable peak dBC value of 135.

A healthy ear exposed to sound levels of 80 dBA over a long period will develop a temporary decrease in hearing sensitivity (Chen, Dai, Sun, Lin & Juang, 2007). Temporary changes in hearing sensitivity typically recover after a period of auditory rest (Chen et al., 2007; Kujawa & Liberman, 2009), but this recovery is limited to the stereocillia and no recovery occurs in the basilar membrane (Feuerstein, 2002; Kujawa & Liberman, 2009; Wang, Yin, Yu, Huang & Wang, 2011). Consequently, repeated exposure to 80 dBA will lead to permanent changes in hearing sensitivity. Taking this into account one can deduce that even at the conservative 80 dBA levels of the EU Directive(European Directive, 2003/10/EC) some employees within the cash centre are still at risk of developing NIHL.

Statistically noise levels between 80 and 85 dBA do not pose a risk of cochlear damage related to the noise. Consideration should, however, be given to vulnerable (susceptible) individuals who could experience cochlear damage below these 'risk levels' (Śliwińska-Kowalska, et al., 2006). Susceptibility to NIHL is influenced by the individual's genetic predisposition, environmental contaminants, (e.g., chemicals), medication, medical conditions, and risk behaviour such as smoking (Niquette, 2012). This implies that environmental, health, and lifestyle issues, combined with the occupational and non-occupational exposure to noise, will influence the individual's risk of developing NIHL. Based on these considerations individuals with a higher susceptibility to develop NIHL might not be sufficiently protected with legislative limits such 85 dBA, currently implemented in various countries, as well as the 80 dBA limits implemented in the EU. The vulnerable employees would consequently not be protected from NIHL when considering these limits. The key to protecting all employees would be to rather implement an integrated HCP for all employees exceeding a $L_{ex,8h}$ of 75 dBA (Vinck, 2015). A level of 75 dBA can be viewed as the medical safe limit of noise exposure where no permanent damage will occur to the auditory system (Mihailovic et al., 2011; Mills & Melnick, 1974). Taking the 75 dBA limit into account, 46.67% of the employees in this study would still be at risk for developing NIHL.

The selection of the maximum permissible noise exposure levels, and the consequent protection requirements and compensation procedures, involves the careful consideration of ethical, social, economic, and political factors, which differ between countries (ISO 1999, 2013). Countries interpret these factors differently and consequently apply the legislation related to these aspects differently. With the current legislation in South Africa, compensation claims related to NIHL in the mining industry alone already cost government an estimated ZAR 72 113513 from 2008 to 2012 (Edwards & Kritzinger, 2012). Lowering the permissible noise level would increase the number of employees eligible for compensation due to occupational NIHL, and taking the already elevated costs into account this is most likely not an economically sound option.

The final conclusion drawn in this investigation is that various employees in the cash centres are exposed to noise levels that will be damaging to the auditory system, although these noise levels do not exceed the current SA legislative PEL of 85 dBA. The peak dBC values do exceed the recommended peak exposure level of 140 dBC and this suggests that an HCP may be beneficial to protect the workers from the hazardous effects of noise exposure in the cash centres.

However, more extensive studies, and on a larger scale, are required to determine the exact noise levels and consequent impact of these noise levels on the employees.

6.3. Clinical Implications

As stated previously, the five major commercial banks in South Africa all make reference to the occupational health and safety guidelines. It is specified that the company occupational health and safety policies are based on the Occupational Health and Safety Act No. 85 of 1993, with the aim of providing a healthy and safe working environment (SA Banking Sector, 2012). The results from this study indicate, however, that the banking industry should consider the implementation of an HCP within the cash centres, as the peak exposure levels exceed the limits specified by the Occupational Health and Safety Act (Act 85 of 1993). The Environmental, Health and Safety (EHS) Guidelines (2007), related to the banking industry, make reference to an acceptable $L_{ex,8h}$ exposure limit of 70 dBA. The data from this study revealed that based on these exposure limits, 73.33% of the employees involved in the study would exceed these exposure limits. The current study consequently provides a baseline for further investigations related to the banking industry's application of regulations related to noise exposure.

The researcher was only able to obtain one unpublished document related to the investigation of noise levels in a cash centre. The current study provides important additional information regarding the noise levels in a cash centre when cash management is taking place. This is contextually relevant information necessary to develop and initiate awareness regarding elevated noise exposure levels in the cash centres in order to motivate for the implementation of HCP in these working environments. Similar to the study by PSM Industrial Hygiene (2012) the current study also concluded that peak exposure levels are higher during coin processing procedures than during note processing. The peak exposure levels also exceed the recommended PEL more often that the $L_{ex,8h}$ exposure levels.

6.4. Critical Evaluation

A critical evaluation of the research project is crucial in order to interpret the findings of the research within the framework of the study's strengths and limitations. These will be discussed below.

6.4.1. Strengths of the study

The current study provided important data related to the noise exposure levels in cash centres during cash management procedures. Cash centres play an integral part in the cash supply chain within the banking industry and little is known of the employment conditions within the cash centres (Fourier, 2008). The current study provided new information regarding the employment conditions related to noise emitted by the cash processing machines within cash centres. In order to implement effective prevention activities, high risk noise exposure activities must first be identified (Sliwinska-Kowalska & Davis, 2012). The current study contributed to the identification of these high risk activities, noting that coin processing procedures create higher peak exposure levels than note processing procedures.

The data obtained in this study will make a valuable contribution towards the banking industry's awareness regarding noise exposure levels during cash management procedures. Effective hearing conservation can only be implemented if both the employer and the employee are fully aware of the risks present in the working environment. Bockstael et al. (2012) found that risk perception, the implementation of the company's hearing conservation protocol, and the use of HPDs are low in companies where the noise levels lie close to the acceptable safe limits. This is a potential risk for the cash centre industry as the noise levels obtained during this study are not very high in comparison to the PEL of SA legislation. Yet, the improved awareness regarding the risk to develop NIHL could contribute to the banking industry's ability to effectively follow the guidelines set out by the Occupational Health and Safety Act No. 85 of 1993.

Nevertheless, the following limitations in the current study were identified and have to be taken into account during the interpretation of the results and the consideration of future research.

6.4.2. Limitations of the study

Several environmental and individual factors can aggravate the development of NIHL. Environmental aspects such as the exposure periods (breaks in exposure allow for some level of recovery), impulsiveness of noise (impulse noise is more damaging than steady state noise), noise exposure beyond the workplace, temperature in the workplace, and the simultaneous exposure to chemicals all influence the progress of NIHL (Śliwińska-Kowalska, et al., 2006). In their study Keifer and Delaney (2002) also investigated the temperature and room humidity to account for a possible effect from these factors. Such factors were not investigated in the current study and this omission limits the consideration of environmental factors within the cash centres that could contribute to the development of NIHL.

Dosimetry measurements were obtained for note processing versus coin processing. Note processing occurs in the teller area of the cash centre, whereas as coin processing occurs in the treasury area. The physical design of these two areas, as well as the number of cash processing machines located in each area, differs. Aspects such as the reverberation of the room and acoustical damping were not taken into account. Secondly, as recommended by OSHA (2008), both area noise sampling and personal noise sampling should be conducted as part of best practice for noise monitoring. The area sampling should be completed with a sound level meter and the different measurements must be indicated on a noise map, in order to identify which areas need to be demarcated as “noise zones” (OSHA, 2008). Due to the nondisclosure agreement signed with bank investigated during the study, a floor plan could not be obtained and thus limits the discussion related to room acoustics and characteristics that could influence the measurements obtained.

An additional limitation of only conducting personal noise dosimetry is that the influence of the microphone placement cannot be controlled. Byrne and Reeves (1999) identified that the variation in dBA measurements obtained during personal noise dosimetry are quite large. The measurement variations are dependent on the microphone position, supporting structures, sound source location and the noise spectrum (Byrne & Reeves, 1999). Duplicate measures that attempt to adjust for these variations would be beneficial.

The sample used in this study was very small, due to the limitation of convenience sampling, related to the security access available at the bank investigated. This limits the ability of the researcher to generalise the findings to the bigger population, as Kumar (2011, p. 212) pointed out: “*the greater the sample size, the more accurately your findings will reflect the true picture.”*

6.5. Recommendations for future research

The findings in the current study created the potential for research relating to various aspects.

Further research is necessary where more extensive noise level measurements are obtained. Both area noise sampling and personal noise sampling should be conducted on a larger scale to obtain a more representative sample of the noise exposure levels during the various cash management processes. As stated previously, area noise sampling will enable the researcher to plot the noise levels, in different locations of the cash centre on a noise map. This will contribute to a more extensive HCP as the ‘noise zones’ can be demarcated.

The current research study was only conducted in the cash centre associated with one of the five major commercial banks. Future studies are necessary to allow for generalisation to the other four major commercial banks, to determine whether the noise levels are elevated in all the banking cash centres.

Individual risk perception must be considered in the design and implementation of hearing conservation programmes. It is essential that both the employer and the employee be educated regarding the matter of NIHL and the effective implementation of an HCP (Arezes & Miguel, 2005). The current study did not investigate the risk perception and awareness related to NIHL in the cash centre industry which will ultimately influence the effective protection of the workers at risk in the working environment.

6.6. Final Comments

Despite the regulations put in place to protect workers from NIHL, occupational hearing loss still persists (Bockstael et al., 2012). Focus is placed on industries known for elevated noise levels, such as mining, milling, and metal work (WHO, 2007). The contribution of these industries to South Africa's GDP is decreasing, however, with more focus being placed on finance, real estate, and the business services. In 2013 these industries contributed 21.5% to South Africa's GDP (Media Club South Africa, n.d.).

Bank cash centres play an important role in the finance industry, but little is known regarding the employment conditions within the cash centres related to noise emitted by the cash processing machines in these cash centres. The current study investigated the noise levels and found that although the daily $L_{ex,8h}$ did not exceed the South African legislative limits of 85 dBA (Occupational Health and Safety Act, 1993; SANS 10083, 2013), the peak level measurements for various employees did exceed the recommended 140 dBC. Considering that 75 dBA is the level where no temporary or permanent damage will occur to the auditory system (Mihailovic et al., 2011; Mills & Melnick,1974), various employees within the cash centre are exposed to noise levels that could be damaging to the auditory system.

NIHL is irreversible with no effective treatment, because once hair cell damage has occurred, the hair cell cannot be regenerated (Hong at el., 2013). Fortunately, NIHL is preventable if the required procedures are put in place. Legislation regarding occupational noise exposure is very diverse, however, and different countries implement the legislation at different noise levels and different levels of complexity (Arenas & Suter, 2014). It is clear that consensus regarding acceptable noise levels in the workplace has not been reached. From the current study, it is clear that these discrepancies could likely also influence the occupational health and safety of employees in the cash centre environment.

As stated previously, the key to protecting all employees would be to rather implement integrated HCP for all employees exceeding a $L_{ex,8h}$ of 75 dBA. Various ethical, social, economic, and political factors have to be considered before such a regulation can be implemented (ISO 1999, 2013).

All industries and protective agencies (such as audiology practitioners) would do well to consider the sobering words of Arenas and Suter), (2014, p. 318):
"In the meantime, workers continue to lose their hearing due to the insufficiency of current legislation and enforcement, combined with either a lack of information or a lack of will on the part of the employers, employees and governmental agencies."

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APPENDICES

Appendix A: Demographic Information Sheet

This demographic information sheet is administered to obtain information related to the employee's demographic information. This study forms part of a Master's Degree research Study at the University of Pretoria: Communication Pathology Department. The completion of the demographic sheet is voluntary and your privacy will be maintained throughout the research protocol.

Please take the time to complete the demographic sheet as honestly as possible

Please answer the following questions

1. Age								
Under 20	20 – 25	26 – 30	31 – 35	36 – 40	41 – 45	46 – 50	50 – 55	Above 56

2. Gender	
Male	Female

3. What is your job title?									
Clerk Treasury		Clerk Balancing		Clerk Cash Centre		Clerk Processing		Controller Treasury	
Custodian ATM		Dept Head		Manager		Teller			
Other: Specify									

4. How long have you been doing this job?								
Less than 1 year		1 – 3 years		4 – 6 years		7 – 9 years		More than 10 years

Appendix B: Ethical Clearance

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Office of the Deputy Dean

7 October 2013

Dear Prof Vinck

Project:	**Noise profile and risk perception regarding noise associated risks in South African bank cash centres**
Researcher:	**C Botha**
Supervisor:	**Prof B Vinck**
Department:	**Communication Pathology**
Reference number:	**25053958**

Thank you for the application that was resubmitted for review.

I am pleased to be able to tell you that the above application was approved by the **Postgraduate Committee** on 17 September 2013 and by the **Research Ethics Committee** on 3 October 2013. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

The Committee requests you to convey this approval to the researcher.

We wish you success with the project.

Sincerely

Prof Sakhela Buhlungu
Chair: Postgraduate Committee &
Research Ethics Committee
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: sakhela.buhlungu@up.ac.za

Appendix C: Informed Consent

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Denkleiers • Leading Minds • Dikgopolo tša Dihlalefi

Faculty of Humanities
Department of Communication Pathology

December 2013

Dear Participant

Please read this information and feel free to ask any questions about the study, before deciding if you are willing to participate in this study.

The aim of the research study is to determine the noise exposure profile and employee attitudes within the bank cash centre.

This research study will be conducted in two phases. During phase one, you will be requested to complete a questionnaire regarding noise exposure within your working environment. During the second phase of the study, randomly selected individuals will be involved in additional noise measurements related to personal noise exposure during a work day.

If you are selected to be involved in the personal noise exposure measurements, you will be required to wear a noise dose Badge throughout your work day. The dose Badge will be attached to your shirt collar and you will be requested to continue with your work activities as usual. The dose Badge will collect data on the individual noise exposure during different activities in the day. You will not be required to monitor or adjust anything on the dose Badge during your work day.

Participation in this study is completely voluntary. At any time during this study, you are free to inform the researcher that you no longer want to participate. All information obtained during this study will remain anonymous and will have no impact on your current employment. The researcher aims to publish the study in an accredited journal.

It will be greatly appreciated if you will consent to participation in this study.

Kind Regards

____
Celeste Botha
Audiologist

____
Prof. B. Vinck
(Supervisor)

____
Dr. L. Pottas
(Co – Supervisor)

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