



**THE AUDITORY EFFECTS OF OCCUPATIONAL EXPOSURE TO
CHEMICAL SOLVENTS**

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DECLARATION

I, FAATIMA NAKHOODA, declare that the research and information obtained for the development of this thesis is of my own original research. The following research has not been submitted to any other university or institute for examination purposes. The following information obtained from other sources has been referenced accordingly and where direct quotes and definitions have been used, direct quotations have been documented and have further been referenced accordingly.

Signed _____ at _____ on _____

Day of _____ 2016

Signature: _____

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ACRONYMS

NIHL:	Noise Induced Hearing Loss
SIHL:	Solvent Induced Hearing Loss
PTA:	Pure Tone Average
PEL:	Permissible Exposure Level
HPD:	Hearing protection devices
HCP:	Hearing conservation programs
OHC:	Outer hair cells
ROS:	Reactive Oxygen Species
ENG:	Electronystagmography
SLM:	Sound Level Meter
DPOAE:	Distortion Product Otoacoustic Emission

ABSTRACT

Recently emerging literature indicates that the combination of solvents and noise have the potential to cause auditory dysfunction. There is limited literature available relating to the effects of SIHL exposure on the auditory system and this highlights the need for this study. The study firstly aimed to determine the combined effects of exposure to solvents and noise on auditory function in workers by conducting a systematic review and meta-analysis. The study further aimed at profiling the audiological results of a group of workers exposed to a variety of solvents at various exposure levels within high and low noise factories. A longitudinal prospective research design was used. The researcher collected data at multiple follow-up times over a six month period to obtain multiple measurements on each worker. The final study sample comprised of 12 workers. Results: Aim one: Heterogeneity was assessed in the selected studies by using the I^2 test. Results revealed that significantly higher odds ($p=0.006$) of acquiring hearing loss when workers are exposed to a combination of solvents and noise as opposed to solvents only. Aim two: Participants were exposed to noise and solvents within the limits, however, pure tone threshold results revealed that all workers experienced hearing loss at 12KHz with a mean of 45dB across all the phases. Results for DPOAEs revealed that all workers had reduced amplitudes across all three phases with the exception of one pass result at one phase for one worker. When pure tone thresholds and OAEs were compared, the statistics indicated that there were no significant differences ($p=0.68$ and $p=0.38$) between pure tone audiometry and DPOAEs. The sample size of the study was too small to yield significant results. Participants reported on various symptoms experienced from exposure to solvents dizziness, headaches and blurry eyes. The present study supports that exposure to solvents may increase the risk of hearing loss due to noise exposure. The researcher recommends that industries should prioritize noise and solvent reduction to prevent hearing loss and the audiologist's role within audiological monitoring of solvent induced hearing loss is emphasized.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will begin with the problem statement and rationale for the study, including a brief background regarding the effects of solvents on the auditory system. This will be further investigated in chapter two, together with supporting literature available. A summary of all the chapters are also outlined. Key definitions utilized in the study are presented, together with the abbreviations.

1.2. Problem statement and rationale

Workers within occupational settings are exposed to various work-related substances that may be hazardous to hearing such as noise, asphyxiants, pesticides, metals and solvents (Johnson & Morata, 2010). Conservation of hearing within occupational environments has been a concern for audiologists over the years due to the effects of increased noise exposure on industrial workers (Fuente & McPherson, 2012). Noise Induced Hearing Loss (NIHL), which is a sensory-neural hearing loss due to long-term exposure to loud noise, has historically been the primary focus of hearing conservation programs within industries. However, recently emerging literature indicates that solvents also have the potential to cause auditory dysfunction (Gopal, 2008). This phenomenon has coined the term Solvent Induced Hearing loss (SIHL) which is used to describe solvents as ototoxic agents that cause hearing loss (Fuente & McPherson, 2012; Fuente & McPherson, 2006; Campo & Maguin, 2007; Mariola, Deepak, & Rodrigues, 2007). Evidence relating to the impact of excessive noise exposure on the auditory system is in abundance (Fuente & McPherson, 2012; Choi & Kim, 2014); however, literature relating to the effect of solvent exposure on the auditory system is limited, particularly within South Africa (SA). This is due to the poor research focus given to this subject. Information relating to solvent exposure effects on the auditory system is valuable due to the large population of South Africans working in industries. Solvents are commonly found in industries that produce rubber, viscose rayon, shoes, furniture, dyes, adhesives, plastic, paint, electronic and printing industries, mining and construction industries, and agricultural settings (Fuente & McPherson, 2012; Mohammadi, Labbafinejad & Attarchi, 2010; Kim, Park, HA, Jung, Paik & Yang, 2005). The main users of solvents in SA are agriculture, mining, the paint, plastics and pulp and paper industries. Painting and coating constitute the largest market sector for solvents and provide the biggest potential within industrial solvents (BMI, 2009). The most recently available statistics is that SA's manufacturing industry is the largest in Africa with a total of 1, 146 000 people employed at the end of June 2012 (Statistics, 2012). Internationally in the United States, more than five million people are exposed to solvents in the manufacturing industry (Gopal, 2008). Although accurate statistics are not

available regarding the number of workers affected by SIHL in SA, it can be inferred that the prevalence of SIHL is considerable due to the large number of industries within the country

Many South African industries produce products that contain harmful solvents, namely the paint and shoe manufacturing industries. Paint and shoe manufacturing industries contains many different solvents that are said to cause damage to the auditory system, therefore, an exposure to a mixture of these solvents could be detrimental to workers' hearing (Fuente, McPherson, & Hickson, 2013). The paints sector particularly has approximately 300 companies and employs approximately 8,000 people (BMI, 2009). This indicates that a large number of South Africans could be at risk for SIHL within this industry specifically.

While the chemical sector makes a substantial contribution to the economy, the impact of such employment on the state of health due to exposure to chemicals and noise is of concern. Chemicals entering the body through inhalation can affect the human body and cause irritation to the skin, eyes and respiratory tract; have a detrimental effect on the nervous system; cause damage to the internal organs, such as the kidneys and liver, and cause diseases like cancer (Steyger, 2009). Mirzaei and Ansari-Moghaddam (2012) reported that the first harmful effects of chemical substances on the auditory system was identified by the philosopher, Avicenna, in 1484. He discovered that using mercury vapor for treatment of head lice could cause hearing loss (Mirzaei & Ansari-Moghaddam, 2012). Even though efforts have been made to understand the mechanisms involved in SIHL, the molecular mechanisms are not well known and still need to be researched.

In addition to the effects of solvents either in isolation or in combination, solvents are classified into high and low priority solvents (high priority solvents include toluene, xylene, styrene, *n*-hexane, trichloroethylene, lead and carbon monoxide; and low priority solvents include mercury, benzene, carbon disulphide and manganese). The available protocols and standards are found internationally with a focus on high priority solvents only e.g. xylene, toluene and ethyl benzene, as there is sufficient research reporting SIHL after exposure to these solvents (Campo & Magun, 2007).

As mentioned above, there is limited literature available relating to the effects of SIHL exposure on the auditory system, the mechanism and pathophysiology of ototoxic agents, as well as minimal research conducted specifically in SA. The lack of awareness of the effects of solvent exposure amongst audiologists in the country highlights the need for this study, as it will provide relevant information for appropriate SIHL management.

Furthermore, studies need to be conducted locally in order to establish the need to adjust the current legislation on exposure levels, as current occupational legislation in SA does not consider solvents as

a hazard to hearing. A large population of South Africans working in industries indicates that many South Africans could be at risk of SIHL, particularly within the paint and shoe manufacturing industries. There have been NIHL programs implemented as well as SA legislation and acts imposed on industries regarding NIHL, but none for chemical exposure. It is therefore necessary for standards and guidelines to be formulated in order to protect the hearing of such workers and include them into SIHL management programs. Furthermore, there are currently NIHL programs implemented as well South African legislation and acts imposed on industries regarding NIHL, but none for chemical exposure.

Due to the limited research available, the study will aim towards firstly conducting a systematic review and meta-analysis to determine the effects of combined exposure of solvents and noise on auditory function as well as profiling the audiological results of a group of workers exposed to varied types and levels of solvents in factories in KZN within high and low noise environments.

1.3. Definitions

HIGH-LEVEL SOUND: Workers who are repeatedly exposed to sound levels that surpass the national action limit value of 85 dBA (Martin & Clark, 2006).

NEUROTOXICITY: Substances that affect the central and peripheral nervous system (Campo & Magun, 2007)

NOISE INDUCED HEARING LOSS (NIHL): Is used to refer to a steady deterioration of auditory function following repeated, long-term exposure to loud noise (Gelfand, 2009).

OCCUPATIONAL HYGIENIST: The Occupational Hygienist has knowledge and experience relating to occupational exposures. An Occupational Hygienist will be able to assess and identify potential exposures in various workplaces and jobs, is able to measure exposures using a variety of different instruments and validated methods and is able to advise management on the best ways to reduce or mitigate exposures and thus reduce the risk of workers developing work related illness (Hills, personal communication, 2014).

OTOTOXICITY: Defined as a drug or other chemical substance that causes functional impairment or cellular damage in the inner ear, especially upon the end organs and neurons of hearing or balance, or the vestibulo-cochlear nerve (Martin & Clark, 2006).

PERMISSIBLE EXPOSURE LEVELS (PELs): A PEL is an upper limit on the acceptable concentration of a hazardous substance in the workplace. It is typically set by national authorities and enforced by legislation to protect occupational safety and health (Johnson & Morata, 2010).

SOLVENT INDUCED HEARING LOSS (SIHL): Is used to refer to hearing loss that is caused by exposure to ototoxic solvents (Fuente & McPherson, 2012).

SOLVENTS: Solvents are liquids that are used to dissolve different substances; they are colourless and have strong odours. Common organic solvents include: toluene, xylene, ethyl benzene etc. (Fuente & McPherson, 2012).

LIPOPHILICITY: The ability of a chemical compound to dissolve in specific products (Fuente & McPherson, 2006)

VOLATILITY: The ability of a substance to vaporize (Fuente & McPherson, 2006)

BIOTRANSFORMATION: The process by which the “body metabolism transforms solvents into water soluble compounds” (Prasher, Al-Hajjal, Aylott, & Aksentijevic, 2005, p. 32)

NEUROTOXICITY: Substances that affect the central and peripheral nervous system (Campo, et al., 2009)

VESTIBULOTOXICITY: Substances that affect the structure and function of the vestibular organ (Campo, et al., 2009)

1.4. Summary of Chapters:

1.4.1. Summary of chapter 1: Introduction

This chapter will begin with the problem statement and rationale for the study, including a brief background regarding the effects of solvents on the auditory system. Key definitions utilized in the study are presented, together with the abbreviations. A summary of all the chapters are also outlined.

1.4.2. Summary of chapter 2: Background and orientation

The proceeding chapter will begin with a brief introduction of the study. An overview of Noise Induced Hearing Loss (NIHL) and Solvent Induced Hearing Loss (SIHL) and their pathophysiology will be presented. The differences between SIHL and NIHL will then be highlighted briefly. This will be followed by a discussion on solvent exposure, particularly within paint and shoe manufacturing

industries. An outline on the available literature regarding the effects of noise and solvents on auditory function will be presented. The chapter will also present the regulations, both nationally and internationally, regarding solvent exposure levels. The role of the occupational hygienist will also be discussed. The chapter will conclude with a discussion on the various methods the audiologist uses to assess auditory function for SIHL.

1.4.3. Summary of chapter 3: Research methodology

This chapter describes the methodological framework employed in this study. The aims, objectives, hypotheses, study design, variables of the study, study sample, sampling technique and participant selection criteria are outlined and described. A description of the investigative procedures used in this study is provided followed by the pilot study results. A brief overview on how the data was analysed is discussed. The chapter concludes with a discussion on the ethical and legal considerations of the study.

1.4.4. Summary of chapter 4: Results and discussion

This chapter provides the results and discussion obtained for this study. The results are presented according to the objectives that were highlighted in chapter three. Tables and graphs were used in order to adequately describe the results obtained in this study. Firstly, results of the systematic review and meta-analysis will be analysed and thereafter results will be discussed in detail. Secondly, a comprehensive discussion of the results of aim 2 obtained in this study is then discussed. The discussion aims at providing possible explanations for the findings obtained.

1.4.5. Summary of chapter 5: Conclusion, implications for future research, strengths and limitations of the study

This is the final and concluding chapter, which provides a summary of the findings as well as clinical and research implications. Limitations and recommendations for future studies are provided.

1.5. Conclusion

The current chapter provided the problem statement and rationale for the study, highlighting the purpose and aims of the study and how the findings of the study can be used to inform policy and legislation. A summary of all the preceding chapters was outlined. Definitions and abbreviations were also provided.

CHAPTER 2

BACKGROUND AND ORIENTATION

2.1. Introduction

The proceeding chapter will begin with a brief introduction of the study. An overview of Noise Induced Hearing Loss (NIHL) and Solvent Induced Hearing Loss (SIHL) and their pathophysiology will be presented. The differences between SIHL and NIHL will then be highlighted briefly. This will be followed by a discussion on solvent exposure, particularly within paint and the shoe manufacturing industries. An outline on the available literature regarding the effects of noise and solvents on auditory function will be presented. The chapter will also present the regulations, both nationally and internationally, regarding solvent exposure levels. The role of the occupational hygienist will also be discussed. The chapter will conclude with a discussion on the various methods the audiologist uses to assess auditory function for SIHL.

2.2. Background and orientation

SIHL is a fairly new concern in the field of audiology and presents new challenges for audiologists. Whilst audiologists are concerned about hearing loss within an occupational setting caused by noise, emerging literature has brought Solvent Induced Hearing Loss (SIHL) to the forefront, highlighting their role in occupational settings to protect hearing and rehabilitate hearing loss obtained as a result of solvent exposure (Fuente & McPherson, 2006). The American Speech and Hearing Association (ASHA) Omnibus Survey (1994) revealed that 45% of practicing audiologists were involved in occupational hearing conservation services. This is as a result of the considerable research and knowledge about NIHL and the methods of preventing it. However, with modern technology and new raw materials in industries, workers are exposed to solvents that could be detrimental to the auditory system in different ways (Fuente & McPherson, 2006). This implies that the scope of practice for audiologists within the occupational setting is expanding. SIHL is relevant for audiologists as the knowledge and awareness of various solvents and their exposure will assist in being able to conduct a full clinical case history; to be able to conduct routine audiological evaluations; to provide auditory rehabilitation and to assess workers for medico-legal issues (Fuente & McPherson, 2006). Furthermore, audiologists will be able to appropriately place workers in hearing conservation programs within various occupational settings, particularly those that have high noise and solvent levels (Hughes & Hunting, 2013).

Many audiologists are unaware of SIHL, as most research results are published in occupational health journals, which are not typically reviewed by audiologists (Fuente & McPherson, 2006). Audiologists

need to keep updated with new knowledge regarding substances that are hazardous for hearing in order to implement programs for such target groups. There is also a need to conduct further research within the SIHL field to expand the literature available, especially with regard to the mechanism and pathophysiology of ototoxic agents, as there is limited research in this area. Furthermore, audiologists have a responsibility to provide information and awareness campaigns to management and stakeholders in order to promote the conservation of hearing among workers. This is particularly important as certain industries expose their workers to varying levels of solvents depending on the task at hand, hence audiologists need to be aware of the risks in order to discuss these risks with management. Audiologists are capable of conducting hearing conservation programs (HCP) for workers exposed to solvents. Johnson and Morata (2010) recommend that adjustments need to be made to the HCP in combined chemical and noise industries. These adjustments include: taking chemical exposures into account when monitoring air exposures, assessing workers who are exposed to chemicals more regularly, as well as using different methods for controlling workers exposures to chemicals. Researchers also suggested that the HCP needs to include short-interval audiometric evaluations, high frequency audiometry, and efficient hearing protection devices (HPD) (Mohammadi, Labbafinejad, & Attarchi, 2010). In order to effectively address these concerns within the SA context, standards and protocols should be informed through evidence based research, however, no studies to date have been conducted in SA, thus the rationale for this study. In order to formulate these guidelines and protocols, it is of worth to understand the **definitions, pathophysiology, similarities and differences between NIHL and SIHL.**

2.3. Noise induced and solvent induced hearing loss: definitions, pathophysiology and similarities and differences of NIHL and SIHL

2.3.1. Noise induced hearing loss

Causes of hearing loss related to industrial workers include acoustic trauma, exposure to noise as well as ototoxic substances such as solvents (Ikharu, Nobuyuki, Hiroichi, & Kazuhisa, 2000). NIHL is a sensory-neural hearing loss due to long-term exposure to loud noise of greater than 85dB's; NIHL is a significant social, occupational and public health problem (Gelfand, 2009). Noise can be defined as any unwanted or unpleasant sound (Johnson & Morata, 2010) and an intensity of sound that impedes the understanding of verbal communication and may cause discomfort to the ears or a decline in hearing sensitivity (Berger, 2003). NIHL is one of the most renowned occupational health diseases in the world (Mirzaei & Ansari-Moghaddam, 2012). According to the World Health Organization (WHO), it is estimated that NIHL is accountable for 16% of the disabling hearing loss in adults (Mirzaei & Ansari-Moghaddam, 2012; Johnson & Morata, 2010).

NIHL is usually a bilateral and symmetrical hearing loss that is irreversible and develops gradually over a period of exposure to high-level sound (Johnson & Morata, 2010; Gelfand, 2009). NIHL occurs at a noise notch of 4000Hz, or sometimes even 3000Hz and 6000Hz; although, this is not the conformed pattern of hearing loss in all cases (Gelfand, 2009). Speech audiometry results are typically within normal limits in the absence of background noise, since the affected frequencies are primarily above the speech frequency range. Speech discrimination in the presence of background noise, however, is typically reduced (Gelfand, 2009).

A decline in hearing sensitivity occurs when there is exposure to continuous high-level sound greater than 85 dBA for 8 hours per day. A-weighting decibels (dBA) is the most commonly used in measuring noise as it is essentially corrected to replicate the sensitivity of the human ear to sounds at different frequencies (Gelfand, 2009). Based on the logarithmic scale, a 3dB increase in the sound pressure level of sound is roughly equivalent to doubling the intensity of the sound, thus illustrating that for sounds that are louder than 85dBA, far less time exposure is required to damage the auditory system (Gelfand, 1997). The intensity, frequency and duration of noise exposure will determine the degree of NIHL (Zhao, Manchaiah, French, & Price, 2010).

2.3.2. The Pathophysiology of NIHL

NIHL results in a variety of anatomical and physiological abnormalities within the auditory system with the damage ranging from subtle disturbances of the metabolic activities of the hair cells to the complete deterioration of the auditory nerve supply and the organ of Corti (Johnson & Morata, 2010). The exposure to high-level sound may affect the auditory structures in various ways, including biological variations in the sensory cells, physiological displacing of hair cells during high-level sound stimulation, changes in the cochlea blood supply with subsequent adjustments in the function of the stria vascularis, damage of the outer hair cells, rupture of Reissner's membrane and detachment of the organ of Corti from the basilar membrane (Martin & Clarke, 2006). Recent literature findings have also revealed similar anatomical and physiological abnormalities of the auditory system due to SIHL.

2.3.3. Solvent induced hearing loss

Solvents are liquids that are used to dissolve substances, they are colorless but have strong odours (Fuente & McPherson, 2012; Fuente, McPherson, & Hickson, 2013). Solvents have a minimum of one carbon and hydrogen atom, it has low molecular weight and high lipophilicity and volatility (Fuente & McPherson, 2006; Tochetto, Quevedo, & Siqueira, 2013). Morata and Little (2002) categorized solvents into high priority and low priority solvents. High priority solvents have higher risk factors, including affects to the central and peripheral nervous systems and irritation to the skin, eyes and respiratory tract. High priority solvents include toluene, xylene, styrene, *n*-hexane,

trichloroethylene, lead and carbon monoxide. Low priority solvents have lower risk factors, including damage to the internal organs, such as the kidneys and liver, and are known to cause diseases like cancer. Low priority solvents include mercury, benzene, carbon disulphide and manganese (Morata & Little, 2002; Chang, Chen, Lien, 2006; Johnson & Morata, 2010; Mirzaei & Ansari-Moghaddam, 2012; Campo & Maguin, 2007; Chang, Shih, Chou, Chen, Chang, Sung, 2003; Morata, 2003; Choi & Kim, 2014). Solvent exposure, particularly in high levels can cause systemic bodily harm.

Research findings indicate that the vapour particles of solvents are inhaled by workers, which are then absorbed via the respiratory tract (Johnson & Morata, 2010). They can also be absorbed through the skin or exposed wound tissue, after which they translocate into the blood stream and travel through the body and affect cells where they interact with tissue that causes dysfunction in the body and certain organs (Baker, Smith, & Landrigan, 1985; Fuente & McPherson, 2012; Yah, Iyuke, & Simate, 2011; Unlu, Kesici, Basturk, Kos, & Yilmaz, 2014). In addition, once solvents are absorbed into the body via inhalation, the body's metabolic system transforms the solvents into components that are present in blood and then excreted in urine. This demonstrates the need to adequately monitor workers exposed to solvents by monitoring their metabolites (blood and urine) for traces that have been in their system.

2.3.4. The pathophysiology of SIHL

High and low priority solvents are said to be ototoxic and affect the auditory system (Morata & Little, 2002). An ototoxic agent is defined as “a drug or other chemical substance that causes functional impairment or cellular damage in the inner ear, especially upon the end organs and neurons of hearing or balance, or the vestibulo-cochlear nerve” (Johnson & Morata, 2010, p. 9). Hence, long term exposure to ototoxic solvents can have specific detrimental effects on the auditory system. These effects include: ototoxicity, neurotoxicity and vestibulotoxicity (Campo, et al., 2009). This triad of complications makes differential diagnosis of SIHL a challenging one as the symptoms are similar to other auditory pathologies such as NIHL. SIHL coupled with noise exposure, makes the relationship even more complex, particularly since so little is understood about the pathophysiology of SIHL (Loukazadeh, Shojaoddiny-Ardekani, Mehrparvar, Yazdi, & Mollasadeghi, 2014).

The documented effects of solvents on the auditory system of humans include: damage of sensory cells and nerve endings in the cochlear and in the auditory pathways, damage to the stria vascularis (Campo et al., 2009), damage to the spiral ganglion cells, retro cochlear damage, vestibular damage and damage to Pillar and Deiters cells of the organ of Corti (Mohammadi, Labbafinejad, & Attarchi, 2010; Kim, et al., 2005). In terms of specific OHC damage, the third row of OHC's is thought to be most vulnerable as it is closest to the stria vascularis (Campo & Maguin, 2007), after which the first and second rows are affected (Fuente & McPherson, 2012; Fuente, McPherson, & Hickson, 2013).

Research also states that certain solvents are found to affect specific areas of the auditory system (Johnson & Morata, 2010). Figure 1 below illustrates the various structures of the auditory pathway that are possibly affected by the solvents (Johnson & Morata, 2010). This implies that specific frequencies may be affected. This information is relevant when making a differential diagnosis and therefore facilitates early identification and management, especially since there are multiple similarities and differences between NIHL and SIHL.

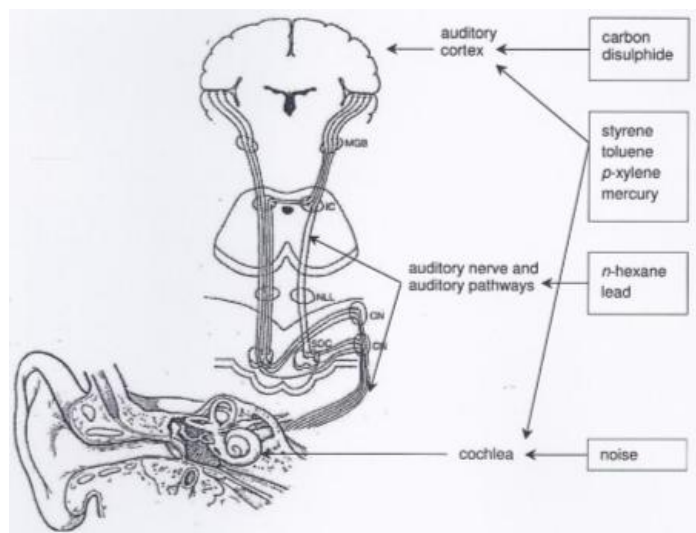


Figure 1. Schematic representation of various solvents with possible site of action along the auditory pathway. Adapted from “Occupational exposure to chemicals and hearing impairment,” by Johnson & Morata, 2010, *Arbete och Halsa*, 44, p. 15. Adapted with permission.

2.3.5. The similarities and differences of NIHL and SIHL on the auditory system

Chemical substances, alone or combined with high-level noise, have become a major concern as contributing to occupational hearing loss (Campo & Magun, 2007). A number of studies have been conducted and have proposed that there is a synergized effect between noise and solvent exposure, resulting in hearing loss (Campo, Maguin, Gabriel, Moller, Angela, Gomez, & Toppila, 2009; Chang et al., 2003; Ikuharu, et al., 2000; Campo, Morata, & Hong, 2013). Literature indicates that exposure to both noise and solvents is more harmful to the auditory system as there is increased damage to the OHC’s (Steyger, 2009; Mariola, Deepak, & Rodrigues, 2007). Therefore, problems arise adequately in the description of the combined effect, as it is not clear as to which specific event leads to auditory dysfunction, that is, does the auditory deficit occur due to noise exposure or solvent exposure or a combination of both.

As discussed earlier, noise and solvent exposure have certain complex differences in terms of their physiological effects on the auditory system. Recently, research has focused on the combined effects of noise and solvents on the auditory system, with the presence of high intensity noise causing an

increase in Reactive Oxygen Species (ROS) or free radicals in the cochlea, which leads to cell death. Toxic levels of ROS are also generated in the body in the presence of solvents and cause dysfunction in the blood-labyrinth barrier, which could lead to permanent hearing loss. Furthermore, solvents affect the OHC's in a specific area, i.e. the middle turn area, where middle frequencies are located (Sulkowski et al., 2002; Choi & Kim, 2014) and this is different from NIHL where the higher frequencies are generally affected (Johnson & Morata, 2010; Tochetto, Quevedo, & Siqueira, 2013). The features of SIHL have been scarcely researched in different occupational settings, however, workers within the paint and shoe manufacturing industry have been identified as high risk groups (Fuente, McPherson & Hickson, 2013).

2.4. Rationale for the paint and shoe industry

Paint and manufacturing of shoes are particular products that contains a mixture of the high priority solvents (Juarez-Perez, Torres-Valenzuela, Haro-Garcia, Borja-Aburto, & Aguilar-Madrid, 2014; Unlu et al., 2014). High priority solvents are present in paint, paint thinners, glue that binds shoes as well as in the spray painting of shoes which results in workers being exposed to a combination of solvents. Individual solvents are reported to cause SIHL, therefore, it is plausible to assume that a mixture of solvents, such as in the case of the paint and shoe manufacturing industries, will have a greater detrimental effect on the auditory system due to the cumulative effect. Fuente and McPherson (2006) reported that paint includes high priority solvents such as toluene, styrene and xylene and low priority solvents such as ethyl benzene, that have been reported to negatively impact the body, and particularly the auditory system. These include damage to the structure and function of the inner ear, neural pathways, central and peripheral nervous system, and the vestibular organ.

There are a few studies in the literature that have assessed workers auditory function within paint industries. In a study by Fuente, and colleagues (2013), they discovered that there are possible adverse effects of solvents on auditory functioning within a paint industry. Seventy-two workers who were exposed to solvents from paints presented with poorer audiological test results than 72 workers who were not exposed to solvents (Fuente, McPherson, & Hickson, 2013). In a similar study, 46 participants who were exposed to solvents within a paint industry were tested for auditory dysfunction. Results revealed that solvent exposed participants presented with poorer audiometric hearing thresholds for most of the frequencies tested as compared to the non-exposed solvent group of workers (Fuente, McPherson, & Hickson, 2011).

Furthermore, the literature reveals that the peripheral hearing system is not the only system affected by solvent exposure from paints. There are reports that the balance system as well as the central auditory system are affected (Fuente, McPherson, & Hickson 2011; Fuente, McPherson, & Hickson,

2013; Fuente, McPherson, & Hormazaba, 2013; Zamyslowska-Szmytke, Piotr, & Sliwinska-Kowalska, 2011; Fuente & McPherson, 2007; Fuente & McPherson, 2007; Juarez-Perez et al., 2014).

Zamyslowska-Szmytke, Piotr, and Sliwinska-Kowalska (2011) reported that of the 60 workers who were employed in paint industries and exposed to a mixture of organic solvents, 53% presented with balance abnormalities. In addition, Fuente and McPherson (2007) conducted various central auditory assessments on workers exposed to solvents within a paint industry. The authors used 50 workers exposed to a mixture of organic solvents and 50 non-exposed workers. The results for the central auditory assessments revealed that non-exposed workers obtained better results than exposed workers. Additionally, workers who were exposed to solvents reported more hearing complaints in daily life listening situations than non-exposed workers. These findings are in contrast to findings by Zamyslowska-Szmytke, Politanski, and Sliwinska-Kowalska (2001), who reported that there was no relationship between hearing loss and solvent exposure in workers in a paint factory in Korea. While a variety of tests have been used in these studies and the data clearly outlines the certainty of SIHL, there is controversy regarding the interaction between noise and solvent exposure, requiring more studies to be conducted. More evidence will also assist in developing permissible solvent exposure levels.

2.5. Solvent exposure levels- the evaluations and recommendations by national and international bodies

Noise in the workplace has exposure standard levels that need to be abided by to be safe for human hearing (Johnson & Morata, 2010). Solvents in the workplace also need exposure standards to protect workers from SIHL. However, due to minimal research on the exposure-response relationship between solvents and hearing loss, there has been no standards stipulated for PELs specific to protect human hearing (Johnson & Morata, 2010).

There are only recommended PELs (refer Table 1 overleaf) for airborne exposure to solvents with none being available in South Africa. International organizations that have set these levels in the United States include:

- National Institute for Occupational Safety and Health (NIOSH),
- Occupational Safety and Health Administration (OSHA) and
- American Conference of Industrial Hygienists (ACGIH) (Fuente & McPherson, 2006).

Table 1

PELs That Are Averaged Over An Eight-Hour Work Shift For Different Solvents

<i>Solvent</i>	<i>OSHA</i>	<i>NIOSH</i>	<i>ACGIH</i>	<i>COSHH</i>
Toluene	200 ppm	100 ppm	50 ppm	100 ppm
Styrene	100 ppm	50 ppm	20 ppm	100 ppm
Xylene	100 ppm	100 ppm	100 ppm	100 ppm
Ethyl acetate	400 ppm	400 ppm	400 ppm	400 ppm
Ethyl benzene	100 ppm	100 ppm	100 ppm	100 ppm
Carbon disulfide	20 ppm	1 ppm	10 ppm	10 ppm
N-hexane	500 ppm	50 ppm	50 ppm	100 ppm

PPM: parts per million.

OSHA: Occupational Safety and Health Administration (U.S.A).

NIOSH: National Institute for Occupational Safety and Health (U.S.A).

ACGIH: American Conference of Industrial Hygienists (U.S.A).

COSHH: Control of Substances Hazardous to Health (U.K.).

Note. Adapted from “Organic solvents and hearing loss: The challenge for audiology,” by Fuente & McPherson, 2006, *International Journal of Audiology*, 45, p. 371.

International legislations to protect workers from SIHL are provided for by the Canadian Centre for Occupational Safety and Health, and Safe Work Australia (SWA). The European Parliament, Brazil and Germany have issued position papers on the negative effects of solvents on hearing (SWA, 2012). In developing countries like SA, there are no regulations or laws regarding SIHL, and industries allow workers to work under adverse conditions without being informed about the consequences. Audiologist’s need to play an active role in the protection of workers hearing within industries. It is envisaged that research studies such as the present, can add evidence to the limited existing body of knowledge so that such evidence can be used to formulate guidelines and regulations. Air monitoring of substances and risk management assessments should be conducted by the industry in order to protect workers from SIHL (SWA, 2012). Air monitoring assessments, where solvent concentrations in the air are monitored, are conducted by occupational hygienists. Occupational Hygienists are professionals who are able to assess and measure solvents in industries, as they have knowledge and experience relating to occupational exposures. Their scope covers many aspects including chemicals, physical stressors (noise, vibration, heat, and radiation), biological stressors (viruses and bacteria), ergonomics etc. A hygienist will be able to assess and identify potential exposures in various workplaces, and will be able to measure exposures using a variety of instruments and validated methods, being able to advise management on the best ways to reduce or mitigate exposures and thus reduce the risk of workers developing work related illnesses (Hills, personal communication, 2014). Therefore, the interaction between the occupational hygienist and the audiologist cannot be over

emphasized. Area air measurements are conducted using personal air sampling pumps, low flow sampling heads, activated charcoal sorbent tubes and a primary calibrator to check flow rates. Personal air sampling is taken for individual workers and the results are sent to a lab for analysis. An analysis is conducted on the number of solvents and volumes of solvents present in the industry (Hills, personal communication, 2014). As mentioned in earlier discussions, pinpointing solvents as the causative agent of auditory dysfunction may be difficult even in a low noise environment. Air sampling may allow the audiologist to make a differential diagnosis especially in industries with low noise levels.

Measurement of solvents includes three areas (SWA, 2012):

- The 8-hour time weighted average (TWA), which represents the average airborne concentration of a solvent over an 8 hour working day, 5 days a week time frame.
- The short term exposure limit (STEL) which represents the average airborne concentration of a solvent over a 15 minute period, as certain solvents are highly toxic even for a brief period of time.
- 'Peak limitation', which represents the maximum airborne concentration of a solvent over the shortest period of time.

The above assessments are prescribed air monitoring protocols and these assessment criteria are provided in various organisational policies and government legislation (Fuente & McPherson, 2012). Methods to monitor auditory function of workers exposed to occupational hazards are outlined by the South African National Standards (SANS) (SANS, 2004). The prescribed clinical protocol for diagnostic audiological testing for occupational hearing loss includes:

- an otoscopic investigation to determine any visible pathology which could have led to the loss of hearing;
- a pure tone conduction test;
- a bone conduction test;
- a speech reception threshold;
- a speech discrimination test;
- a full Immittance test battery including tympanometry, ipsi- and contra lateral acoustic reflex testing;
- oto-acoustic emission (OAE) testing including transient oto-acoustic emission testing and/or distortion product emission testing; and
- any other audiometric test procedures to determine the degree of hearing loss.

These tests enable the audiologist to differentiate between cochlear and retro cochlear pathologies, and can therefore be used as a guideline for monitoring SIHL. Studies have shown that high frequency audiometry is also a useful test to include in an audiological assessment as it can be used as an early indicator of hearing loss (Fuente & McPherson, 2012; Unlu et al., 2014; Tochetto, Quevedo, & Siqueira, 2013). In addition to the above mentioned tests, central auditory assessments should include: binaural integration, temporal resolution, temporal ordering, auditory closure and electrophysiology testing (Fuente, McPherson, & Hickson, 2013). Fuente & McPherson (2012) conducted an assessment of 100 workers who were exposed to solvents, after which the above mentioned central auditory assessments were conducted and the results revealed signs of solvent exposure, indicating their value for assessing SIHL. The wide variety of the tests indicates that different procedures are needed to detect solvent exposure in different parts of the auditory system. Thus, audiologists need to consider the wide range of effects that solvent exposure might have and include a comprehensive test battery to monitor the affected workers. In a study conducted by Sulkowski, et al. (2002), Electronystagmography (ENG) investigations revealed significant abnormalities of 47.5% in the exposed group of workers to solvents. Therefore, research suggest that the vestibular organs could also be compromised and specific tests should be used to assess these functioning's. The monitoring of auditory function within an occupational setting can be attained through various audiological tests mentioned above. However, pure tone audiometry and Distortion Product Otoacoustic Emissions (DPOAE) will be conducted in this study. These tests are important for monitoring of hearing function due to its sensitivity, accuracy and ability to detect auditory dysfunction (Gelfand, 2009).

Audiologists further need to conduct air and noise measurements within industries in order to monitor contributing factors to hearing loss. Noise measurements using a Sound Level Meter (SLM) and Personal Dosimeter for noise readings in various areas of the factory are essential. The measurement time intervals are chosen to best represent the type and duration of the noise present at different locations in order for noise assessments to be adequately covered (SANS, 2004).

2.6. Conclusion

In summary, SIHL is a recently emerging facet within the field of Audiology. There is limited research available on the topic of solvents and auditory dysfunction and this needs to be further explored. SIHL is not within the scope of practice of audiologists, however, audiologists need to be aware of SIHL in order to assess and manage this population. A profile of auditory function and reported symptoms, together with parallel air measurement readings for solvents and noise of those exposed to solvents in either high or low noise environments may assist in better understanding the impact of solvents on the auditory system. Therefore, the research question for this study is: “what is the audiological profile of a group of workers exposed to solvents in factories in KZN?”.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

The preceding section included the literature review and the research question. The following section will focus on the research methodology which guided the research process by organizing the acquisition of data and then extracting meaningfulness from the data (Leedy & Ormrod, 2013). This section identified the aims, objectives, study design, participant selection, data collection method, and data collection instrument and data analysis procedures.

3.2. Aims

The aims of this study were:

1. To determine the combined effects of exposure to solvents and noise on auditory function in workers by conducting a systematic review and meta-analysis.
2. To profile the audiological results of a group of workers exposed to solvents in high and low noise level factories in KZN.

The methodology for each of these two aims will be presented.

3.2.1. Aim 1

3.2.1.1. Objectives

The objectives of aim 1 were:

To assess the combined effect of solvents and noise versus noise or solvents only on the auditory function of workers within various industrial settings through a systematic review and meta-analysis of peer reviewed papers (refer Appendix A for submission to journal for publication).

3.2.1.2. Types of studies included into review

Experimental, cross sectional studies comparing the audiometric results of groups of workers exposed to noise and solvents versus noise or solvents only.

3.2.1.3. Types of participants

Workers were exposed to a combination of noise and solvents, as well as noise or solvents only, within various occupational settings. The workers were of either gender and consisted of ages ranging from 18-68 years old.

3.2.1.4. Types of interventions

Various audiological tests were conducted on workers who were exposed to noise and solvents.

3.2.1.5. Types of outcome measures:

Primary outcome

Hearing loss in workers exposed to solvents only vs. both noise and solvents.

Secondary outcomes

To identify secondary auditory dysfunctions, this included:

- Balance disorders
- Upper limit of hearing affected

3.2.1.6. Search methods for identification of studies:

Electronic searches

To perform a systematic review of the combined effects of solvents and noise on auditory function, a search was conducted for peer reviewed publications from 3 different databases. The databases used were Google scholar, Pubmed/Medline and Science direct/Scopus. The following search words were used on all 3 databases; “audiology OR solvents OR hearing loss OR industry”; “audiology OR solvents OR hearing loss”; “chemical ototoxicity”; “solvent induced hearing loss”; “industrial solvents and their effects on hearing”; “audiologist OR solvent induced hearing loss”, “audiology OR chemicals OR hearing loss OR industry”, and “xylene OR toluene OR hearing loss”.

Other additional searches

Full-text copies of each of these articles were obtained and read in detail by the review authors. In addition, the references of each article were reviewed to identify possible papers that were missed by the study search. This method of reviewing references of each article was used in order to cross check results and guarantee that all relevant articles were being used in the review.

3.2.1.7. Data collection and analysis:

Identifying studies

Full-text copies of each of these articles were found; all authors of this review paper independently reviewed the articles to ensure that all articles met the inclusion criteria. If one of the review authors were unclear, authors discussed the articles inclusion/exclusion together. Inclusion criteria included: (1) combined effect of solvents and noise, (2) studies conducted on human beings only, (3) use of audiological tests on participants. Once papers were screened, the abstracts of all records were

retrieved to identify obvious exclusions. The reference list of each article was perused to identify possible studies that were missed by the study search. Figure 2 below provides a summary of the number of studies retrieved from each database. A total of 13 studies were included into the review. The included studies and the characteristics of studies are summarized in Appendix B.

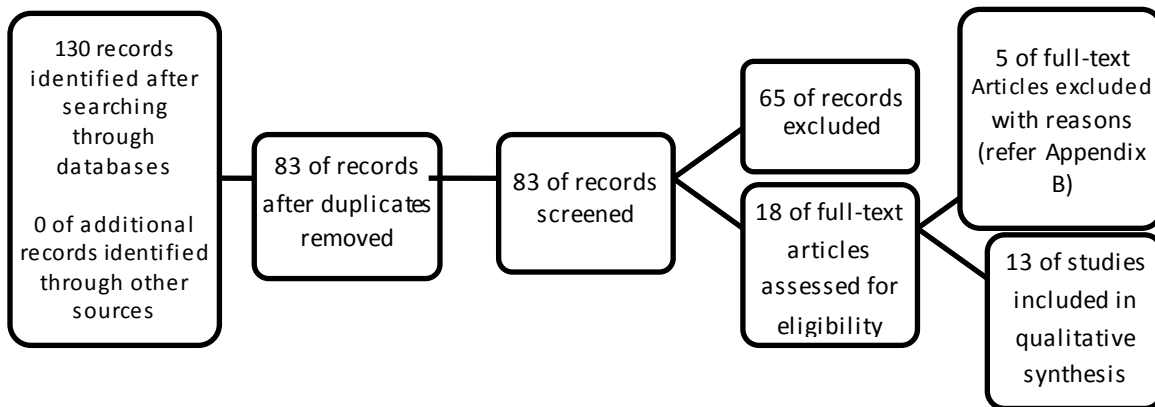


Figure 2. Database search results.

Assessment of methodological quality

Heterogeneity was assessed in the selected studies by using the I^2 test. This test measures the extent to which the results of the studies were consistent. There was heterogeneity evident (high I^2 ($I^2 \geq 50\%$)), therefore the fixed effect model was utilized for analysis.

Data extraction

The studies were categorized according to: year, country, article title, exposure, objective, design, results, conclusion and references (refer Appendix C).

Data analysis

A meta-analysis was carried out and statistical heterogeneity was assessed. The fixed effect model was used and the odds ratio was calculated for statistical heterogeneity. The pooled estimates for dichotomous outcomes are reported as ORs with 95% CI. The primary comparison was risk of hearing loss in the noise and solvent exposed group versus noise only or solvents only exposed group. Other pair wise comparisons included solvent exposed groups versus a control group of no noise or solvent exposure. Heterogeneity of effect sizes was assessed using the I^2 statistic (measure of consistency across studies) (Higgins, Thompson, Deeks, & Altman, 2003). As heterogeneity was

present (i.e. $I^2 \geq 50\%$), the random effects method was used to estimate a pooled effect size (i.e. odds ratio). All analyses were performed using STATA version 13.0 (StataCorp, 2013). A p-value of <0.05 (two-tailed) was considered statistically significant except for the heterogeneity test where a p-value cut-off of less than 0.10 (one-tailed) was used.

3.2.1.8. Ethical considerations

Permission to conduct the review was granted by the Social and Human research Ethics committee (University of KwaZulu- Natal), protocol reference number HSS/0637/015M (refer Appendix D).

3.2.2. Aim 2:

3.2.2.1. Objectives

The objectives of aim 2 were:

1. To profile the noise measurements, air measurements and audiometric results of factory workers within paint and shoes factories exposed to varied types and levels of solvents at three intervals over a period of six months.
2. To compare the pure tone thresholds to DPOAE amplitudes in a group of workers exposed to solvents in order to determine the possibility of sub-clinical hearing loss.
3. To describe the symptoms that workers associated to their exposure to solvents.

3.2.2.2. Hypotheses/ critical assumption

The hypothesis under investigation was to detect whether exposure to chemical solvent/s in the presence of low and high levels of noise resulted in the decrease in auditory function in a group of workers using an audiological test battery. Based on the body of evidence, it was assumed that exposure to solvents both in low and high noise environments are likely to induce auditory pathology.

These measurements were conducted at 3 intervals (at 0 months, at 3 months and at 6 months) in line with chosen study design.

3.2.2.3. Study design

A longitudinal prospective research design was used to enable the researcher to determine if there were any changes in the exposure condition, using purposive sampling (Berg & Latin, 2004). The researcher collected data at multiple follow-up times over a six month period to obtain multiple measurements on each worker. Longitudinal studies are able to evaluate the effects of any risk factors on the state of human health due to its ability to measure exposure levels at an individual level (Leedy & Ormrod, 2013). A pilot study was chosen as individual sample sizes were small, thus the study was conducted on a smaller scale.

3.2.2.4. Study sample

Sample size

The study sample was calculated to consist of 43 factory workers exposed to high levels of solvents (confirmed by air measurement readings) and low levels of noise (confirmed by noise level measurement readings) (Sartorius, personal communication, 2014), and other inclusion criteria as stipulated in section 3.2.2.7. The proposed sample size ensured that an 80% power to detect a medium standardized mean difference (or effect size) of 0.25 in auditory function in a design with three repeated measurements, with the correlation between observations on the same subject is 0.50, and the alpha level is 0.05 or 5% (Sartorius, personal communication, 2014).

The researcher encountered many barriers during the recruitment process. Ten paint industries and one shoe manufacturing industry were approached to participate in the study; eight industries denied the researcher access. The researcher was denied access into the industries due to lack of co-operation from managers or due to company policies and regulations. There are only a few paint and shoe manufacturing industries within KwaZulu-Natal and these industries were targeted because the researcher is currently situated in KwaZulu-Natal. Industries out of KwaZulu-Natal were not targeted due to logistical and financial reasons. After much persistence, only two paint industries and one shoe manufacturing industry were included in the study. The sample size was still too small, thus a shoe manufacturing factory within KwaZulu-Natal was thereafter approached and the researcher was granted access. Shoe manufacturing factories present with similar solvents as paint factories thus it was targeted.

The 43 workers were recruited from two paint industries and one shoe manufacturing industry within the eThekweni district in the KwaZulu-Natal province (see Table 2 overleaf) (refer Appendix E). The researcher declares that there was no relationship between the researcher and the chosen sites. The three industries were combined in this study to increase the studies sample size as it was difficult to find industries that have high levels of solvents and low levels of noise in KwaZulu-Natal. Both the industries were common with regards to exposure to the common solvents. From the 43 workers recruited from the paint industries, only 24 workers agreed to participate in the study. Of the latter, 19 workers did not participate, either by refusal or due to shift clashes and work constraints. From the 24 workers that agreed to participate, one worker did not meet the inclusion criteria and 11 workers did not arrive for testing.

Final sample size

The total number of participants for testing was 12 (total of 24 ears) (refer to Figure 3 overleaf). Descriptions of the sites were as follows:

Table 2

Study Population Site

	NAME	LOCATION	NO. OF EMPLOYEES	MANUFACTURE
FACTORY 1	CHEMSPEC	VERULAM	43	PAINTS
FACTORY 2	PROPAINTS	DURBAN		PAINTS
FACTORY 3	VILLA FOOTWEAR	CLAIRWOOD		SHOES

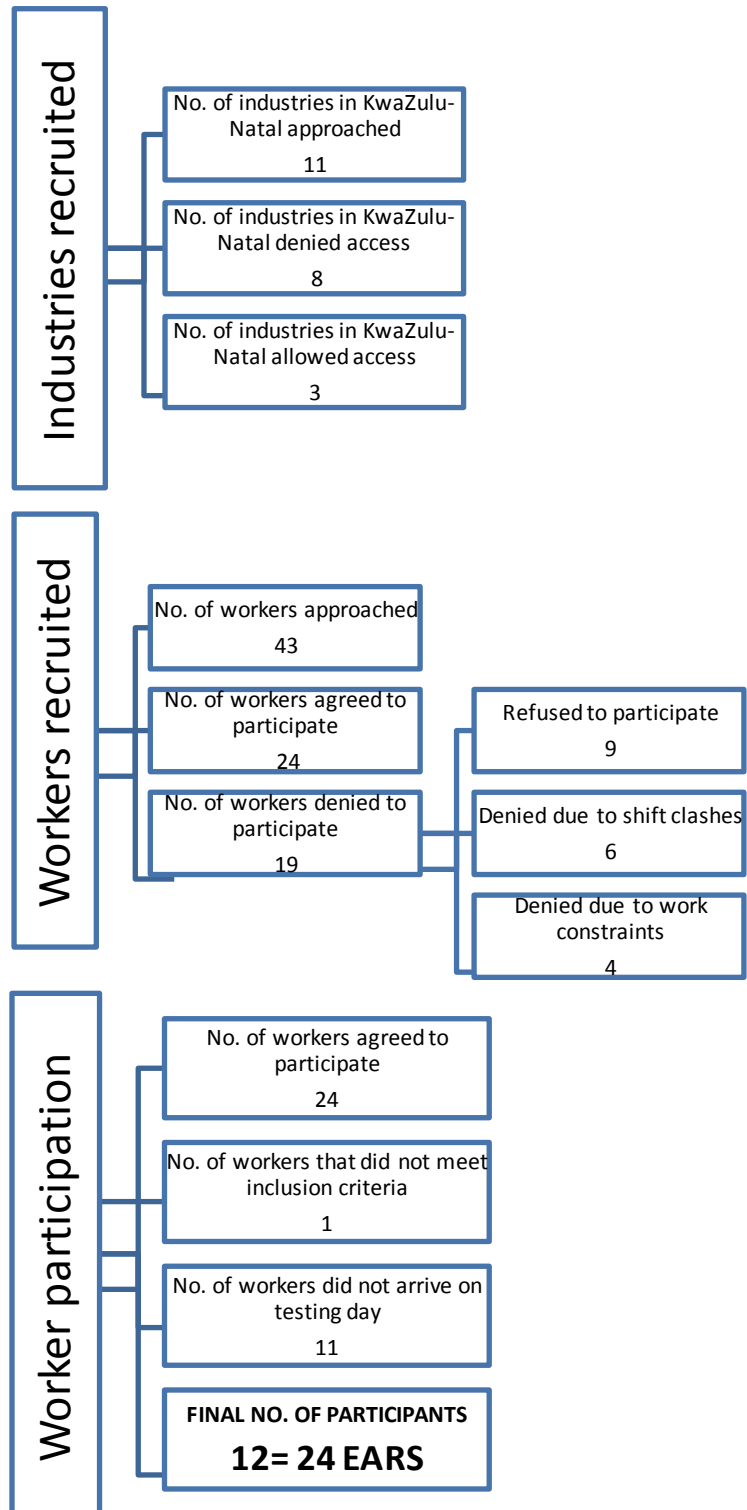


Figure 3. Flow diagrams representing how the study sample was obtained.

3.2.2.5. Demographical profile of the study sample

The final study sample comprised of 12 workers from KwaZulu Natal. There were a total of 11 (92%) males and one (8%) female. The participants ages ranged between 20 and 50 years with a mean age of 34.9 years. The average work experience of all participants was 8.2 years (range one year to 23 years) in the same environment. One (8%) out of 12 participants revealed that they used noise protection devices and two out of 12 participants (17%) used masks to protect themselves from solvent exposure. The exact type of devices used and the duration of time the devices were used for were not obtained. The demographical details of the study sample are reflected in Table 3 below.

Table 3

Demographics of Workers

NO.	GENDER	AGE	NO. OF YEARS WORKED	NOISE PROTECTION	SOLVENT PROTECTION
1	Male	32	3	No	No
2	Male	29	2	No	No
3	Male	24	1	No	No
4	Male	38	15	No	No
5	Male	45	23	No	No
6	Male	43	15	No	No
7	Male	39	9	No	No
8	Male	22	2	Yes- earplugs	Yes- mask sometimes
9	Male	49	15	No	Yes- mask sometimes
10	Female	50	2	No	No
11	Male	20	-	No	No
12	Male	28	3	No	No

3.2.2.6. Sampling technique

Convenience sampling was used to sample the study sites. Purposive sampling was used to secure participants to meet the inclusion criteria, being considered appropriate as the workers were used for a particular purpose (Leedy & Ormrod, 2013). A rationale was provided regarding the selection criteria of participants in order for the sample to be representative of the population (Welman, Kruger, & Mitchell, 2005). In the context of this study, purposive sampling was appropriate to recruit participants due to the time constraints. The participants needed to meet the inclusion criteria, which was determined through the pretest questionnaire (refer Appendix F).

3.2.2.7. Inclusion and exclusion criteria

The following sample selection criteria for participants were used:

- 50 years of age and younger

An upper age cut-off limit was stipulated as research reports the high prevalence of hearing loss in the older population (Martin & Clark, 2006).

- *No confounding variables that would contribute to auditory dysfunction*

If participants presented with confounding variables such as: a history of hearing impairment from birth or childhood, middle ear infections and hearing impairment from injury or disease; they were not included into the study as it could negatively influence the results (Martin & Clark, 2006).

The following exclusion criteria applied:

- *Any medication that could be toxic and cause hearing loss*

Medication could negatively affect the auditory system and therefore influence the results of the study.

- *Medical conditions such as Tuberculosis, meningitis, viral infectious diseases, history of high fevers, kidney diseases*

These medical conditions could negatively affect the auditory system and therefore influence the results of the study (Martin & Clark, 2006).

- *Workers who did not have a 24 hour rest period from their last exposure to noise*

Noise can negatively impact on the auditory system thus workers were only included if they had a rest period, away from noise, for 24 hours or more (Gelfand, 1997; SANS, 2004).

3.2.2.8. Data collection procedure

Three phases were conducted at all three industries, these include phase 1, phase 2, rest day and phase 3. The diagrams below provide a summary and a detailed description of the data collection procedure (see figure 4 overleaf).

The data collection procedure was conducted at 0 months, then at 3 months and again at 6 months to obtain the relevant data for a longitudinal study. At 0 months: phase 1, phase 2, rest day and phase 3 was conducted. At 3 months and 6 months: only phase 3 was conducted to obtain test results from the workers.

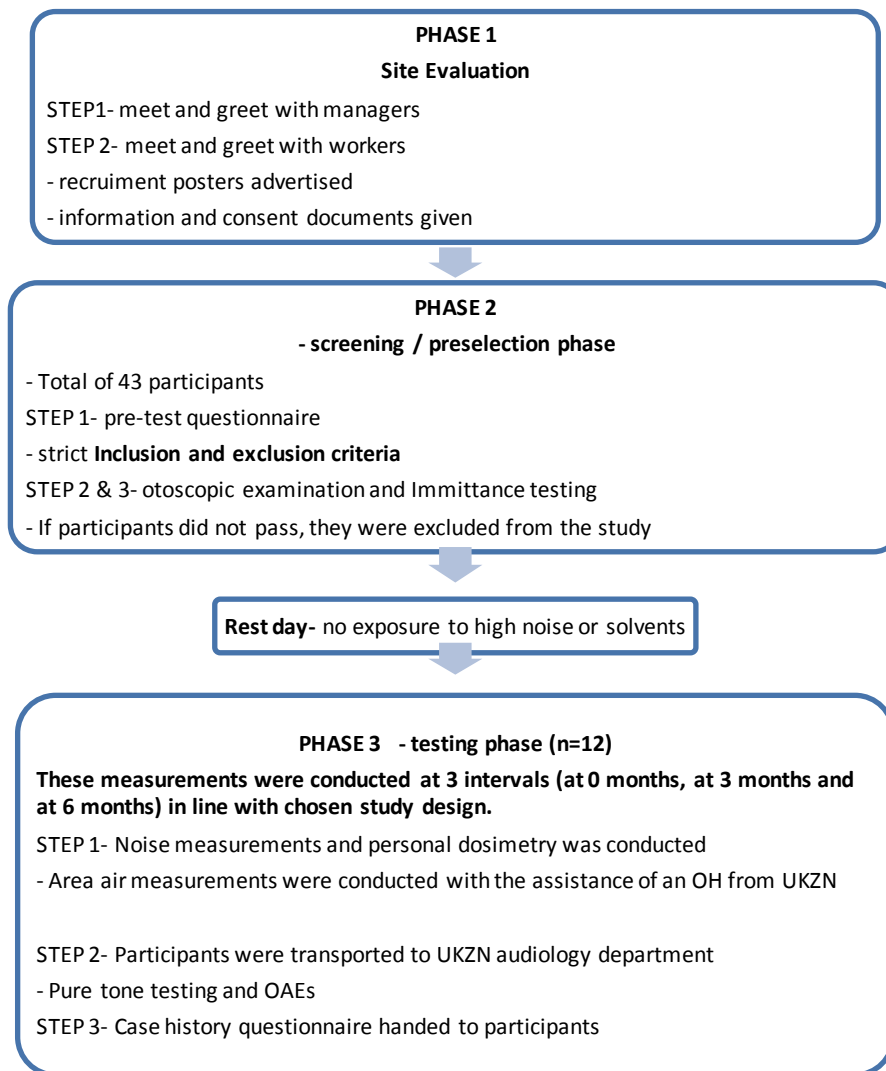


Figure 4. Phases during the data collection procedure- detailed

Phase 1- SITE EVALUATION:

Step 1: The researcher met with the managerial teams of the factories to present a PowerPoint presentation (refer Appendix G) on the background and purpose of the study.

Step 2: Once permission was obtained to conduct the study, the researcher met with the factory workers in stages, depending on their shifts, during which time they were verbally informed about the study, given information documents (refer Appendix H), and invited to participate. This supplemented the recruitment posters (refer Appendix I) placed around the factory inviting them to participate in the study, as well as provided them with details of the researchers' contact details and whereabouts if they were interested in participating. Consent forms (refer Appendix J) were handed out to the workers who agreed to participate in the study. The documents were available in both English and isiZulu (refer Appendix H and J). At the end of the meeting, the workers were given informational pamphlets

(English and isiZulu) (refer Appendix K) regarding occupational hearing loss and protection of hearing in the work environment with the managers permission.

Phase 2- Screening phase:

Step 1: Participant pre-selection criteria: Workers were screened in order to qualify to continue in the study, this information was ascertained through a pre-test questionnaire. The first purpose of the pre-test questionnaire was to ascertain the working environment of the worker. The workers were asked to state what area of the factory they work in, how long are their shifts and how long they have been working in the factory for. The second purpose of the pre-test questionnaire was to monitor workers for confounding variables in order to exclude them from the study.

Step 2: Verification of outer and middle ear functioning

The purpose of Step 2 was to confirm normal outer and middle ear functioning. This was done via Otosopic Examinations and Tympanometry testing. All data was recorded on a data record form (refer Appendix L). All participants needed to pass the criteria for otoscopic examination and tympanometry to continue with the study. If participants did not pass, they were excluded from the study and referred to the company's occupational health and safety nurse (refer Appendix M). All participants who had normal outer and middle ear function and who met the inclusion criteria were selected for the study.

Otosopic examination:

Purpose: An otoscopic examination is conducted to assess if there are any evident structural malformations of the outer ear, for example discharging ear, perforations in the ear drum, impacted wax or foreign bodies. It determines any need for cerumen management, and can assist to detect any factor that may affect an individual's hearing (Gelfand, 2009).

Data collection instrument: A Welch Allyn otoscope was used to perform this examination and different sizes of speculum were selected according to the participant.

Interpretation parameters for participants: Participants ears needed to be free of the following in order to pass the examination:

- Any evident structural malformations of the outer ear, for example discharging ear, perforations in the ear drum, excessive cerumen or foreign bodies.
- Any malformations of the pinna (Gelfand, 2009).

Tympanometry

Purpose: This test provides the objective means of determining the amount of mobility present within the middle ear system when the pressure is applied to the tympanic membrane. The test also assesses the Eustachian Tube functioning. It also determines middle ear pathologies such as stiffness of the auditory ossicles and confirms other test battery results (Gelfand, 2009).

Data collection instrument: The Madsen Zodiac middle ear analyser was used to conduct tympanometry testing. The middle ear analyser had been calibrated. Different sizes of probe tips were selected according to the participant.

Interpretation parameters for participants: Participants needed to fulfill the following criteria stipulated by Hodgson (1980) (Gelfand, 2009) in order to pass the examination:

- A Type A tympanogram bilaterally
- A static compliance value of between 0.2-1.8 ml
- A peak middle ear pressure of between -50daPA and +50daPA
- A ear canal volume value of between 0.2ml-2.0ml

Results from the screening assessments (otoscopic examinations and tympanometry) revealed that 12 workers assessed had passed the screening phase and were included into the study and one worker failed the screener due to middle ear infections and was excluded from the study.

Rest day

According to SANS, audiological testing should be done after at least 24 hours have elapsed from workers last exposure to noise; therefore, participants' were tested after this time frame had passed for accurate results. The participants were tested on their second day off, the first being their day away from the factory, and this was explained to them during the process of inviting them to participate. There is no literature suggesting the length of time solvents remain in the body, therefore workers used the 24 hour rest period before testing, this being based on noise exposure standards.

Phase 3- Testing and measurement phase:

These measurements were conducted at 3 intervals (at 0 months, at 3 months and at 6 months) in line with chosen study design.

Step 1: The researcher conducted noise measurements at the industry using a personal dosimeter for noise readings in various areas of the factory to obtain overall readings for workers. The measurement time intervals were chosen to best represent the type and duration of the noise present at different

locations in order for noise assessments to be adequately covered (SANS, 2004). See Figure 5 below for noise sampling procedure.

Area air measurements were conducted at the industry using personal air sampling pumps, low flow sampling heads, activated charcoal sorbent tubes and a primary calibrator to check flow rates. Personal air sampling was taken for individual workers. Air sampling measurements were taken with the assistance of an occupational hygienist from UKZN who has volunteered her services and equipment for the study. Air sampling results were then sent to a lab in Pretoria (Chemspec) for analyses. Analyses were conducted on the number of solvents and volumes of solvents present in the industry. See Figure 6 overleaf for air sampling procedure.

The noise sampling procedure was as follows (SANS, 2004):

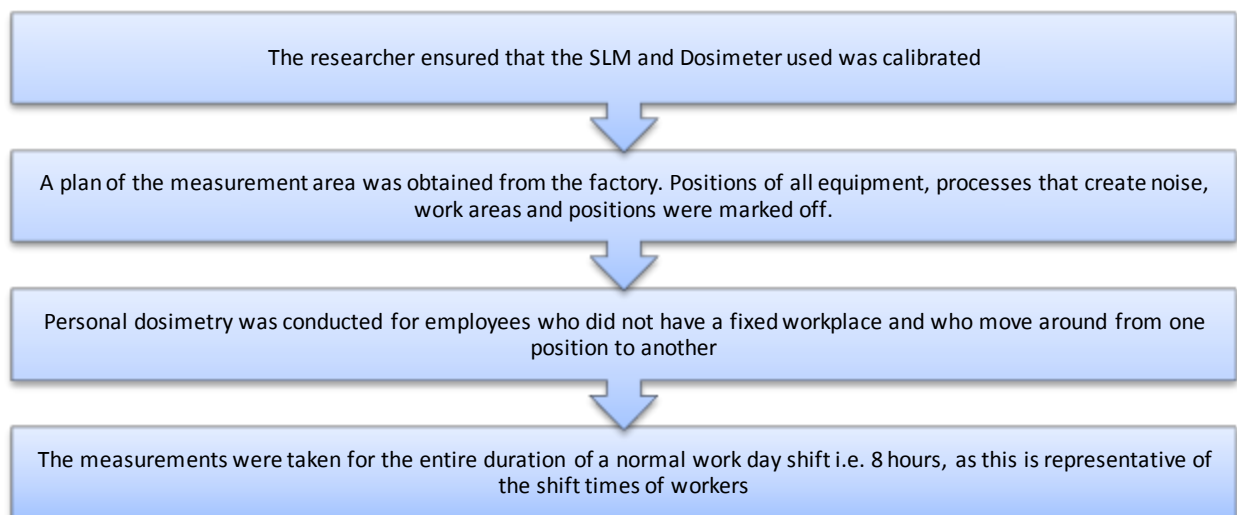


Figure 5. Noise sampling procedure (SANS, 2004).

The air sampling procedure was as follows (NIOSH, 1994; Hills, personal communication, 2014):

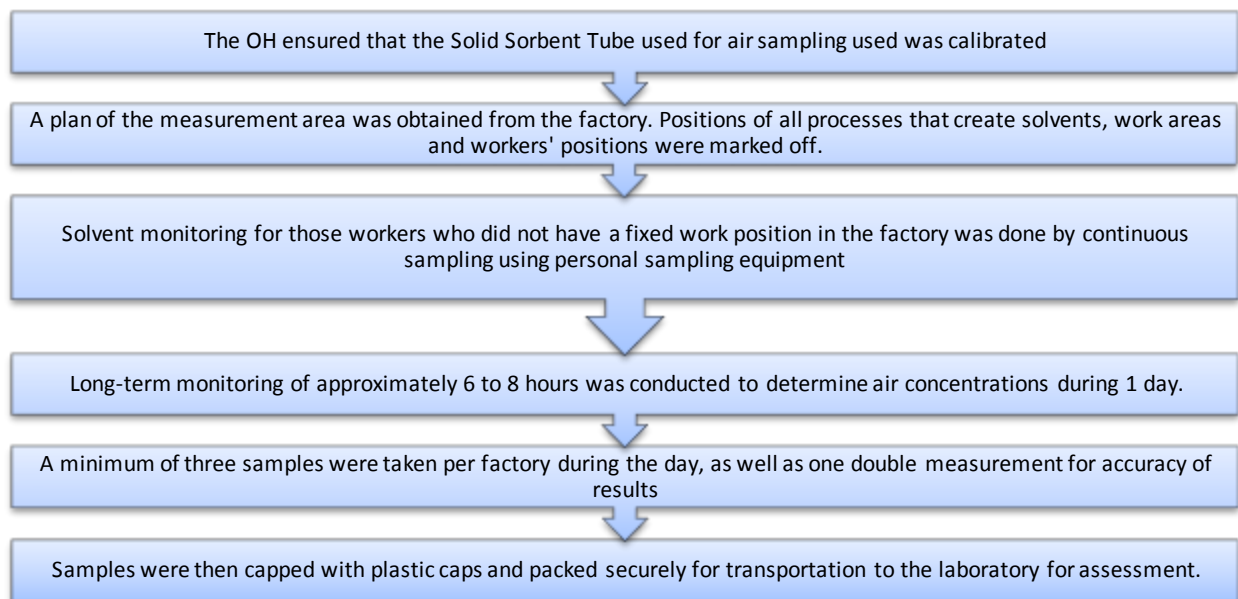


Figure 6. Air sampling procedure (NIOSH, 1994; Hills, personal communication, 2014).

Step 2: Audiological testing

The purpose of this step was to obtain relevant data to conduct the study. This was done via pure tone audiometry testing and Distortion Product Otoacoustic Emissions (DPOAEs) and results were recorded on an audiogram (refer Appendix N).

Pure Tone Audiometry:

Purpose: Pure tone testing describes the auditory sensitivity and identifies the thresholds at which the patient hears. It is also done to assess the functioning of the conductive mechanism. In the presence of a hearing loss, the results will indicate the degree of hearing loss (Gelfand, 2009).

Data collection instrument: The GSI 61 diagnostic audiometer was used to conduct pure tone testing. Calibration of the equipment was conducted. Testing was conducted in an audiometric soundproof booth using supra-aural earphones.

Interpretation parameters for participants: Participants presenting with hearing thresholds were placed into the following categories (Gelfand, 2009):

NORMAL HEARING:	0dBHL-25dBHL
MILD HEARING LOSS:	26-40dBHL
MODERATE HEARING LOSS:	41-55dBHL
MODERATELY SEVERE HEARING LOSS:	56-70dBHL

SEVERE HEARING LOSS: 71-90dBHL
PROFOUND HEARING LOSS: > 90dBHL

DPOAEs:

Purpose: DPOAEs were conducted to assess outer hair cell functioning of each participant.

Data collection instrument: The Biologic Corp AudX OAE meter was used to conduct OAE testing. The diagnostic test 750- 8000 Hz was implemented.

Interpretation parameters for participants: Normal outer hair cell functioning was determined by the distortion product minus the noise floor being **6dBnHL** and above (DF-NF= 6dB).

Participants were transported by the researcher to the UKZN Audiology Department for these tests to be carried out so that they were tested in a suitable testing environment. The Department has the equipment, facilities and controlled noise environment, which is also free from any hazardous materials and chemicals. The Audiology Department at UKZN Westville granted the researcher access to the audiology equipment for the duration of the testing phase (refer Appendix O). The participants were requested to sign an indemnity form (English and isiZulu) (refer Appendix P) stating that they were transported under their own risk and the researcher was not to be held liable for anything that may happen. The researcher provided refreshments during the testing periods. Workers who presented with hearing loss during the testing were referred for further management,

According to SANS, audiological testing should be done after at least 24 hours have elapsed from workers last exposure to noise (SANS, 2004); therefore, participants' were tested after this time frame had passed for accurate results. The participants were tested on their day off, thus there was no interference with on-going production. There is no literature suggesting the length of time solvents remain in the body, therefore, workers used the 24 hour rest period before testing, which is based on noise exposure standards.

Step 3: Case history questionnaire

Case history questionnaires were handed out to participants to obtain information regarding their work history, health conditions and symptoms experienced from exposure to solvents (English and isiZulu) (refer Appendix Q).

The table overleaf provides the timeframe when data collection was carried out (see Table 4 overleaf):

Table 4

Data Collection Timeframe

Task	Industry	Date
Meet with managers for presentation	1	08.04
	2 & 3	09.04
Put up recruitment posters	1	08.04
	2 & 3	09.04
Meet with workers for presentation	1	08.04
	2 & 3	09.04
Hand out information document & consent document	1	08.04
	2 & 3	09.04
Conduct air and noise measurements 1	1	08.04
	2 & 3	09.04
Send air samples to lab 1	1-3	10.04
Conduct screening phase- pre-test questionnaire/otoscopic/Immittance	2 & 3	11.04
	1	13.04
Conduct testing 1	2 & 3	11.04
	1	13.04
Conduct air and noise measurements 2	2 & 3	09.07
	1	10.07
Send air samples to lab 2	1-3	11.07
Conduct testing 2	2 & 3	11.07
	1	13.07
Conduct air and noise measurements 3	2 & 3	08.10
	1	09.10
Send air samples to lab 3	1-3	10.10
Conduct testing 3	2 & 3	10.10
	1	12.10

3.2.2.9. Reliability and validity

A questionnaire was utilized for one aspect of the study and reliability and validity was obtained by conducting a pilot study, and modifications to the questionnaire were made accordingly. To ensure the validity and reliability of the questionnaire, simple and easy to interpret questions were used (Leedy & Ormrod, 2013). To further ensure reliability and validity, specific questionnaire techniques were used to obtain the relevant information required from participants. Unbiased questions and negative phrasing were avoided in the questionnaire i.e. questions were worded in a manner that did not give clues about preferred or more desirable responses. Appropriate closed ended questions were used and to avoid any ambiguity. In order to prevent the misunderstanding of questions, a pilot study was conducted, which is discussed below. For the purpose of this study, a questionnaire from a study by Govender, Govender & Matthews (2012) was adapted and used to compile a comprehensive and easy to understand questionnaire. This study was used as it addressed the similar requirements for the current study. Repeated audiometric measures and air measurements improved the reliability of the data obtained. All equipment used was calibrated according to the relevant standards.

3.2.2.9.1. Pilot study

Convenience sampling was used to select the participants from a computer industry within the eThekweni district (refer Appendix R). Pilot study participants were recruited by researchers being present at the venue and informing the participants regarding the study.

Eight participants were selected from the above-mentioned institution to participate in the pilot study, based on the availability of the workers. The workers completed the questionnaire and were asked to record their opinions on the suggestion page provided (English and isiZulu) (refer Appendix S). The workers were asked to comment on the time taken to complete the questionnaire, comments on the clarity of the questions as well as any suggestions on the questions asked. The pilot study was conducted in one day and took approximately two hours to complete.

3.2.2.9.2. Results of the pilot study

Results from the pilot study included the following recommendations from the pilot study participants:

- Repeated questions were removed.
- Information given to participants had incorrect grammar and was adjusted.
- Clarity of questions was adjusted.
- Case history questionnaire did not have a place to sign, this was added in.
- Further examples were given to participants in the case history questionnaire for time frame of work hours.
- Words that were unfamiliar in the case history questionnaire were changed.
- Numbering in the pretest questionnaire was adjusted.
- Uniformity of words across questionnaires were used.

The editorials were completed and the new case history questionnaire (refer Appendix Q) and pre-test questionnaire (English and isiZulu) (refer Appendix F) were given to the participants.

3.2.2.10. Analyses of results for aim two

With the assistance of a statistician the results were analysed according to the objectives of the study. For **objective one**, descriptive analysis methods were used in terms of percentage counts, bar graphs and pie charts to profile the air measurements, noise measurements and audiometric results of workers exposed to solvents at three intervals over a period of six months.

For **objective two**, frequency patterns and group means of thresholds over time (0 months, 3 months and 6 months) was used to determine if there were any changes from the baseline over time. Further analysis of the data was obtained by using the McNemar test in order to answer objective two. The test was used to test for significance to compare change in auditory function between low frequencies, mid frequencies and high frequencies of Pure Tones and DPOAEs for left and right ears. Alpha was set at 5%. Data was analysed in the following way:

Mean of thresholds for pure tone testing =

Low frequencies (250Hz and 500Hz) compared to air and noise measurements.

Mid frequencies (1 KHz) compared to air and noise measurements.

High frequencies (2 KHz, 4 KHz, 6 KHz, 8 KHz and 12 KHz) compared to air and noise measurements.

Mean of thresholds for OAE measurements =

Low frequencies (750Hz) compared to air and noise measurements.

Mid frequencies (1 KHz) compared to air and noise measurements.

High frequencies (2 KHz, 3 KHz, 4 KHz, 6 KHz and 8 KHz) compared to air and noise measurements.

This test was chosen as it is able to test for significance in smaller sample sizes. The McNemar test is a non-parametric test which is used for correlated proportions in the marginal's of a two by two contingency table (Stokes, Davis, & Koch, 1995). These two by two tables contain information collected from matched pairs, therefore in this study pure tone audiometric threshold and DPOAE amplitudes were conducted on each worker at each of the three phases, thus making these two tests, matched pairs. The responses were classified into pass and fail responses based on the normative data. It must be stated that due to the nature of the above mentioned tests, a direct comparison between the two tests could not be made because they evaluate auditory function differently. Therefore in order to test the hypothesis, raw air conduction thresholds and DPOAE amplitude data was obtained from twelve participants (left and right ear results were recorded) in each of the three phases and was analysed using the McNemar Test. All the above calculations were performed using SPSS version 20 software.

For **objective three**, descriptive analysis methods were used in terms of a pie chart to describe the symptoms that workers associated to their exposure to solvents.

3.2.2.11. Ethical and legal considerations

This study took into account ethical considerations. This involved informed consent, rights to privacy, protection from harm, confidentiality and honesty between professionals (Leedy & Ormrod, 2013). The researcher completed a course in Research ethics training curriculum (refer Appendix T) and Protecting human research participants (refer Appendix U). Permission to conduct this research study was obtained once the proposal was submitted to the University of KwaZulu-Natal Biomedical Research Ethical Committee for approval (refer Appendix V). Letters were sent to the institutions chosen to approve the research being conducted (refer Appendix W).

The participants were provided with an information document (refer Appendix H) and were asked to sign an informed consent (refer Appendix J). All documents were translated by teachers who are first language speakers (refer Appendix X). All documents were then back translated to English by an audiologist in order for all documents to be understood clearly by participants. All documents were read out to participants who are illiterate.

Confidentiality of information was assured by allocating a number to each assessment result, thus no personal information was exposed. Research results are locked in a cabinet and only accessed by the researchers involved in this study. The participants were informed that they have the right to withdraw from the study at any point.

The researcher dressed in accordance with the company regulations whilst based at the industry. The researcher explained to each participant the nature of the study, explained each procedure clearly and gave instructions in the participants first language (English and isiZulu) (refer Appendix Y). The researcher informed the participants that the procedures will not cause harm to them and that all necessary infection control measures were put into place during testing. The participants were clearly explained that the testing is free as well as no incentives were given for participation in the study. The questionnaire was completed in a room and will remain private and confidential. All participants were informed about the results of the tests and if any test result warranted further referrals, then recommendations were provided to the participant and the information was forwarded to the occupational health nurses within the industry (refer Appendix M). At the end of the session, workers were given a copy of their results as well as informational pamphlets (refer Appendix K) regarding occupational hearing loss and protection of hearing within a working environment. Results were also given to management of the industries, with permission from the participants, in order for them to review the data and assist in managing workers. A summary of the study findings will be provided to the industries on completion of the study.

The Occupational Hygienist supervised the researcher during the data collection procedure to ensure accurate solvent samples are taken (Hills, personal communication, 2014) and was given a research report on completion as well as full acknowledgement in the study. The researcher attended lectures and training at UKZN Howard College regarding the “Basic Principles of Occupational Hygiene” over the period of four days for 30 hours (3rd to 6th March, 2014) (refer Appendix Z) in order to gain more practical knowledge on the collection and interpretation of solvent samples. Data collection tools for noise and solvent measurements were sourced from the Department of Occupational Hygiene at UKZN Howard College. Contact has been made with the department and acceptance has been granted for equipment to be used (refer Appendix AA). A letter to the Head of Department was prepared for submission once ethical clearance was granted as a courtesy measure to use the equipment under the supervision of a lecturer.

3.3. Conclusion

This chapter provided the methodological framework for the study and was presented in accordance to the aims and objectives. Aim one was to determine the combined effects of exposure to solvents and noise on auditory function in workers by conducting a systematic review and meta-analysis. The methods of the systematic review were highlighted and the outcome measures were outlined. The data analyses process was discussed and was carried out to reveal the results of the systematic review and meta-analysis in the next chapter. A longitudinal, prospective research design and pilot study was used to meet the criteria of aim two. Aim two was to profile the audiological results of a group of workers exposed to solvents in factories in KZN. Both descriptive and inferential statistics were used. All ethical requirements were adhered to throughout the research process. The next chapter presents the results and discussion obtained from this research study.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Introduction

The preceding section included the methods and analyses of data for the aims of the study. The following section focuses on the results and discussion of the aims of the study. The purpose of aim one was to determine the combined effects of exposure to solvents and noise on auditory function in workers by conducting a systematic review and meta-analysis. Aim two was to profile the audiological results of a group of workers exposed to varied types and exposure levels of solvents within high and low noise environments in factories in KZN. An objective related to this aim further compared two audiological tests, namely, pure tone audiometry and DPOAEs in monitoring hearing function of workers exposed to solvents and noise across three phases. The results and discussion are presented in accordance with the objectives of the study as specified in the methodology.

4.2. AIM ONE

To determine the combined effects of exposure to solvents and noise on auditory function in workers by conducting a systematic review and meta-analysis.

4.2.1 Results

For the current objective, a total of 130 peer reviewed citations were comprehensively reviewed. Of these, 13 papers (3197 workers) were eligible for inclusion. See Appendix BB for a summary of participants' particulars. The participants' ages ranged from 18 to 68 years. The studies had the following similarities: all selected studies were conducted on human participants, various audiological tests were conducted across all 13 studies; workers were exposed to a combination of noise and solvents, noise only or solvents only in all the studies; all studies were conducted in industries with the participants being workers based at the industries. Overview of the meta-analysis results will be presented according to the outcome measures.

Table 5 overleaf describes the participants in the studies. The participants were divided into total number of participants recruited and the total number of participants that were used in the study (cases). The participants were further categorized into noise exposure only; solvent exposure only, combined noise and solvent exposure and control.

Table 5

Description of Number of Participants in Studies

AUTHORS	Total	N only (tot)	S only (tot)	N+S (tot)	Control (tot)	N only (cases)	S only (cases)	N+S (cases)	Control (cases)
Barba et al. (2005)	172		82	52	38		20	16	4
Lobato et al. (2014)	198	42		57	99	7		3	
Hughes & Hunting (2013)	503	148	65	220	70	11	3	12	6
Rizk & Sharaf (2010)	140	50		60	30	9		14	1
Chang et al. (2003)	346	105		131	110	34		89	26
Metwally et al. (2012)	222	70		93	59	44		59	10
Botelho et al. (2009)	152	81		71		13		33	
Mohammadi et al. (2010)	337	173		164		60		113	
Chang et al. (2006)	174	58		58	58	26		50	3
Ikuharu et al. (2000)	54	19		23	12	5		12	3
Kim et al. (2005)	328	146	18	13	151	25	5	7	9
Prasher et al. (2005)	379	153	13	174	39		4	57	2
Schaper et al. (2008)	192	86		106		53		64	
TOTAL	3197	1131	178	1222	666	287	32	529	64

4.2.1.1. Data synthesis:*Solvents and noise present in studies:*

Figure 7 below represents the solvents and noise present in the studies. Ten articles (77%) contained exposure to noise and a mixture of solvents (methyl ethyl ketone, toluene, xylene and methyl isobutyl ketone); while two studies concentrated on exposure to noise and toluene only (15%) and one study concentrated only on exposure to noise and carbon disulphide (8%).

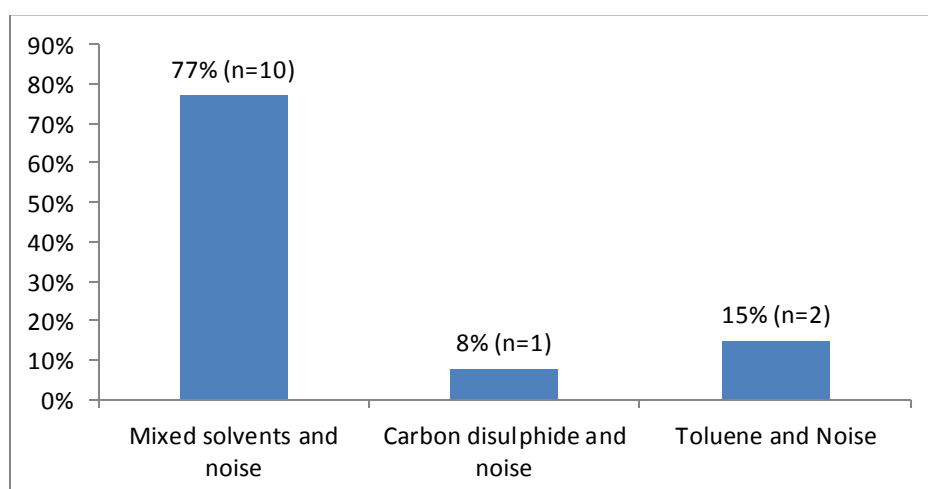


Figure 7. Solvents and noise present in studies.

Types of audiometric tests used:

Table 6 below shows the various audiometric tests used in each study.

Table 6

Description of Various Audiometric Tests Used in Studies

AUTHORS	TESTS USED
Barba et al. (2005)	Pure-tone audiometry
Lobato et al. (2014)	Pure-tone audiometry
Hughes & Hunting (2013)	Pure-tone audiometry
Rizk & Sharaf (2010)	Pure-tone audiometry
Chang et al. (2003)	Pure-tone audiometry
Metwally et al. (2012)	Pure-tone audiometry, Otoloscopic examinations
Botelho et al. (2009)	AC, BC, SRT, SRS, Otoloscopic examinations
Mohammadi et al. (2010)	Pure-tone audiometry
Chang et al. (2006)	Pure-tone audiometry, Otoloscopic examinations
Ikuharu et al. (2000)	Pure-tone audiometry, High frequency audiometry
Kim et al. (2005)	Pure-tone audiometry
Prasher et al. (2005)	Pure-tone audiometry, OAEs, ABR, VNG and Posturography, Otoloscopic examinations, Tympanometry, ART
Schaper et al. (2008)	Pure-tone audiometry

Abbreviations used: SRS (Speech Recognition Score)- VNG (Videonystagmography)- AC (Air Conduction)- BC (bone Conduction)- SRT (Speech Reception Testing)- OAEs (Oto-acoustic Emissions)- ABR (Auditory Brainstem Response)- ART (acoustic reflex threshold)

4.2.1.2. Primary outcomes:

Total prevalence of hearing loss:

The total number of all the participants were 3197, of this, 35% (n=912) presented with hearing loss as a result of noise exposure only; solvent exposure only and combined noise and solvent exposure.

Of the 1222 participants (total of all participants exposed to noise and solvents), 43.3% (n=529) presented with auditory pathology as a result of the combined exposure to noise and solvents. The data revealed that the prevalence of hearing loss in the noise and solvent group was significantly ($p<0.001$) higher than the other groups in 10 out of the 13 studies analysed with Pooled OR of 2.754. Many studies did not have a solvent only group as solvents often coincide with noise in the working environment. Of the 178 participants (total of all participants exposed to solvents) 32 participants presented with auditory pathology as a result of exposure to solvents only. Figure 8 overleaf shows the prevalence of hearing loss amongst the four groups for each of the included studies.

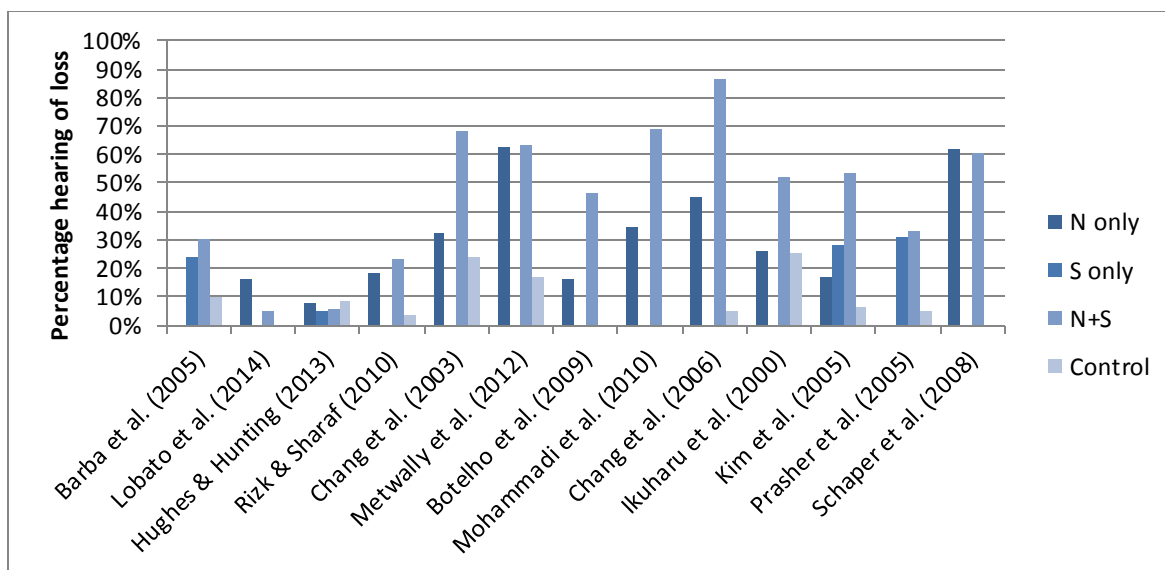


Figure 8. Prevalence of hearing loss amongst four groups

A total of 2285 participants (71%) did not present with any form of auditory pathology, despite their exposure to both solvents and noise or to solvents only or noise only. The combined estimate of the effects of solvents and noise versus noise only or solvents only obtained an odds ratio of 2.146 (see table 7 below). Table seven below and Figure 9 overleaf identifies that there is a significantly higher pooled odds of hearing loss in noise and solvent exposed group compared to solvent only exposed group (Pooled OR=2.15, 95% CI: 1.24-3.72, p-value=0.006). The large majority of participants exposed to noise and solvents showed effects of hearing loss.

Table 7

Noise plus Solvent vs. Noise Only

Heterogeneity chi-squared = 56.14 (d.f. = 10) p = 0.000				
I-squared (variation in OR attributable to heterogeneity)= 82.2%				
Estimate of between-study variance Tau-squared = 0.6659				
Test of OR=1 : z= 2.72 p = 0.006				
STUDY	OR	[95% Conf. Interval]		% Weight
Lobato et al. (2014)	0.278	0.067	1.147	6.61
Hughes & Hunting (2013)	0.719	0.308	1.675	9.22
Rizk & Sharaf (2010)	1.386	0.543	3.540	8.79
Chang et al. (2003)	4.425	2.555	7.664	10.56
Metwally et al. (2012)	1.025	0.539	1.950	10.16
Botelho et al. (2009)	4.543	2.136	9.661	9.65
Mohammadi et al. (2010)	4.173	2.647	6.579	10.92
Chang et al. (2006)	7.692	3.102	19.076	8.93
Schaper et al. (2008)	3.055	0.825	11.303	7.07
Kim et al. (2005)	5.647	1.748	18.237	7.68
Ikuharu et al. (2000)	0.949	0.529	1.700	10.42
D+L pooled OR	2.146	1.239	3.718	100.00

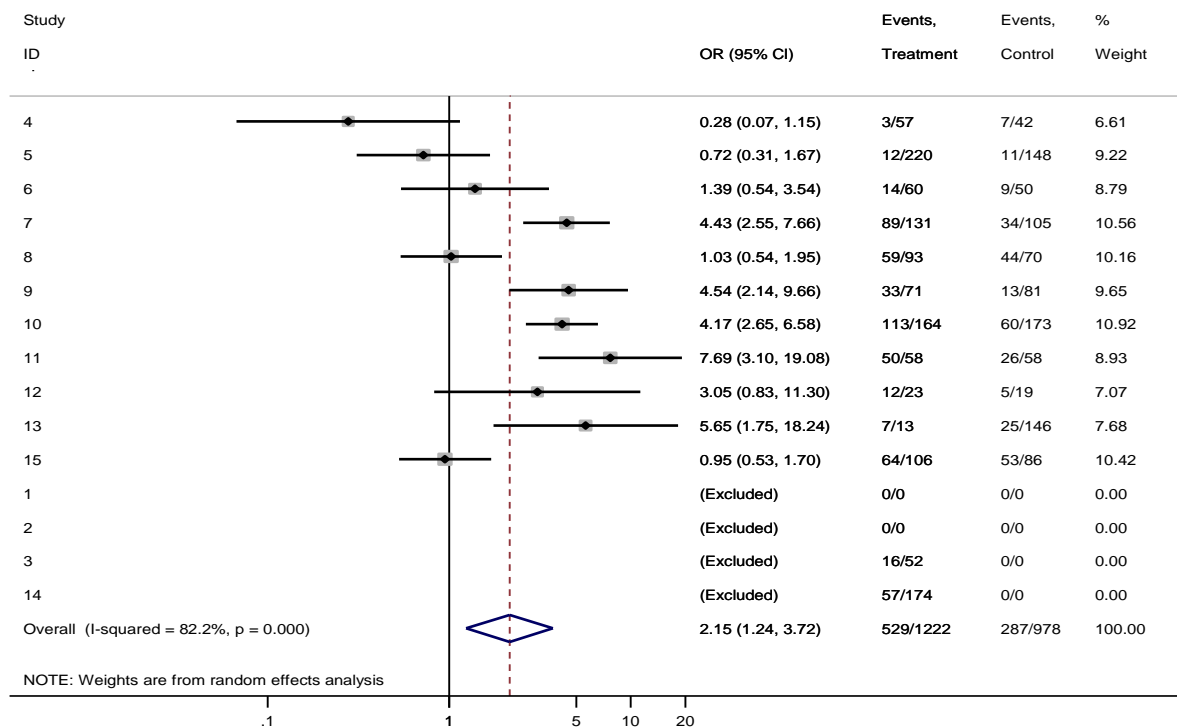


Figure 9. A forest plot indicating noise plus solvent vs. noise only.

4.2.1.3. Secondary outcomes:

In terms of secondary auditory dysfunctions, only one study reported on the effects of solvents and noise on the upper limit of hearing. Results of the study indicated a reduction of the upper limit of hearing which was the largest in the combined noise and solvent group (Ikuharu, et al., 2000). With regards to balance disorders, Prasher et al. (2005) reported on the effects of solvents and noise on hearing and balance in workers. The audiological tests that were used to assess workers balance were VNG (Videonystagmography) and Posturography. Results revealed that 32% of workers in the solvents and noise group had abnormal posturography and VNG results. It was concluded that the effects of a mixture of solvents on the auditory system appears to occur both at the end organ level as well as in the nervous pathway (Prasher et al., 2005).

4.2.2. Discussion

The current review provided evidence of the effects of combined exposure of solvents and noise on the auditory system revealing a higher prevalence (77%) of hearing loss in the noise and solvent group than the other groups in the studies analysed. Kim et al. (2005) reported in a study conducted on workers within the aviation industry that the prevalence of hearing loss in the noise and solvent group was higher than the other groups (54.9%), and similarly, Chang, Chen, Lien, and Sung (2006) reported that the results revealed a higher prevalence of hearing loss in the toluene and noise group (86.2%) when compared to those exposed to noise only (44.8%). Both studies also revealed that the

effect of solvents on the auditory system appears to occur both at the end organ level as well as in the nervous pathway (Mohammadi, Labbafinejad, & Attarchi, 2010).

As reported in the studies, long term exposure to ototoxic solvents can have specific detrimental effects on the auditory system. These effects include: ototoxicity (substances that affect the structure and function of the inner ear and the neural pathways); neurotoxicity (substances that affect the central and peripheral nervous system) and vestibulotoxicity (substances that affect the structure and function of the vestibular organ) (Campo, et al., 2009). This triad of complications makes differential diagnosis of SIHL a challenging one as the symptoms are similar to other auditory pathologies such as NIHL. SIHL coupled with noise exposure, makes the relationship even more complex, particularly since so little is understood about the pathophysiology of SIHL (Loukzadeh, et al., 2014). Thus, research needs to further understand the route of exposure of solvents in order to address this issue, as noise exposure routes have been extensively researched.

Research findings indicate that the vapour particles of solvents are inhaled by workers, which are then absorbed via the respiratory tract (Johnson & Morata, 2010). They can also be absorbed through the skin or exposed wound tissue, after which they translocate into the blood stream and travel through the body and affect cells where they interact with tissue that causes dysfunction in the body and certain organs (Baker, Smith, & Landrigan, 1985; Yah, Iyuke, & Simate, 2011; Unlu et al., 2014; Fuente & McPherson, 2012). In addition, once solvents are absorbed into the body via inhalation, the bodies metabolic system transforms the solvents into components that are present in blood and then excreted in urine. Solvents within the body have the potential to interact with various systems within the body, including the auditory system. The key elements with regard to adverse effects on the auditory system depend on the following three issues:

- the toxicity of the solvent,
- the rate of absorption and
- biotransformation (the process by which the “body metabolism transforms solvents into water soluble compounds”) (Prasher et al., 2005, p. 32; Loukzadeh, et al., 2014; Lobato, De Lacerda, Goncalves, & Coifman, 2014).

Research findings regarding the effects of solvents on the auditory system of humans include: damage of sensory cells and nerve endings in the cochlear and in the auditory pathways, damage to the stria vascularis which is the “fluid-producing cell layer on the outer wall of the cochlear duct” (Campo et al., 2009, p. 9), damage to the spiral ganglion cells, retro cochlear damage, vestibular damage and damage to Pillar and Deither cells of the organ of corti (Mohammadi, Labbafinejad, & Attarchi, 2010; Kim, et al., 2005). Regarding inner ear damage, Campo and Maguin (2007) reported that solvents

infiltrate the cochlear and contaminate the tissue as opposed to contaminating the inner ear fluids. The mechanisms involved in auditory damage consist of the solvents travelling via the blood stream and through the stria vascularis, diffusing through the membranes of the cells constituting the outer sulcus, and impairing the organ of corti (Campo & Maguin, 2007; Morata, 2003; Sulkowski, Kowalska, Matyja, Guzek, Wesolowski, Szymczak, Kostrzewski, & Przemyslaw, 2002). Campo, Lataye, Loquet, and Bonnet (2001) in Campo and Maguin (2007) have observed disrupted membranes and concluded that solvents use the outer sulcus as the main route of intoxication to reach the outer hair cells (OHC's). Research has shown that solvents then poison the hair cells, which results in the membranous structures becoming disorganised and causing hair cell death (Campo et al., 2009). In terms of specific OHC damage, the third row of OHC's is thought to be most vulnerable as it is closest to the stria vascularis (Campo & Maguin, 2007), after which the first and second rows are affected (Fuente & McPherson, 2012; Fuente, McPherson, & Hickson, 2013). Furthermore, solvents affect the OHC's in a specific area, i.e. the middle turn area, where middle frequencies are located (Sulkowski et al., 2002; Choi & Kim, 2014) and this is different from NIHL where the higher frequencies are generally affected (Johnson & Morata, 2010; Tochetto, Quevedo, & Siqueira, 2013).

As discussed by the above mentioned study, individual solvents are reported to cause SIHL (Chang et al., 2003) therefore, it is plausible to assume that a mixture of solvents will have a greater detrimental effect on the auditory system due to the cumulative effect. From the studies reviewed, participants from 11 out of the 13 studies were exposed to a mixture of solvents and these participants presented with hearing loss.

In terms of audiological tests that were conducted, all the studies used pure tone audiometry testing by assessing the frequency range of 125Hz to 8KHz whilst one study assessed the upper limit of hearing (Ikuharu, et al., 2000). In the study by Ikuharu, et al. (2000), it was observed that there was an occupational effect of noise and solvents on the upper limit of hearing in workers. The results had shown noise levels and solvent levels were within occupational exposure limits. There was no significant correlation found between upper limit of hearing and pure tones and the organic solvent concentrations in the working environment. The reduction of upper limit of hearing was largest in the combined group (Ikuharu, et al., 2000). Therefore, it is recommended that high frequency audiometry be used in the audiological assessment of workers as it can be used as an early indicator of SIHL (Fuente & McPherson, 2012). Another study included transient and distortion product otoacoustic emissions (OAEs), auditory brainstem potentials (ABR), VNG and posturography (Prasher et al., 2005). The VNG investigations in this study revealed significant abnormalities to the vestibular organs in the group of workers exposed to solvents. More recently, researchers have confirmed that the balance system is affected by solvents. A study in 2011 by Zamyslowska-Szmytke, Politanski, and Sliwinska-Kowalska (2011) discovered that balance abnormalities in solvent exposed workers

indicated subclinical damage, mainly the central part of the vestibular system and body-movement coordination (Zamyslowska-Szmytko, Politanski, & Sliwinska-Kowalska, 2011). The wide variety of the tests indicates that different procedures are needed to detect solvent exposure in different parts of the auditory system. These varieties of tests enable the audiologist to differentiate between cochlear and retro cochlear pathologies, and can therefore be used as a guideline for monitoring SIHL. Thus, audiologists need to consider the wide range of effects that solvent exposure could have on the auditory system and include a comprehensive test battery to monitor the affected workers (refer Appendix CC overleaf for article submitted to journal for publication).

APPENDIX CC

The effects of combined exposure of solvents and noise on auditory function-a systematic review and meta-analysis¹

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Abstract

Objective: To assess the combined effect of solvents and noise versus solvents only or noise only on the auditory function of workers.

Data sources: Peer reviewed publications from 3 different databases.

Data extraction: Two researchers independently screened the results.

Review methods: Published articles which included noise and/or solvent exposure or combined effects of solvents and noise, studies conducted on human beings only and the use of audiological tests on participants. **Results:** Thirteen papers were eligible for inclusion. The participants' ages ranged from 18 to 68 years. Results revealed that 24.5% presented with hearing loss as a result of noise exposure only; 18% presented with hearing loss due to solvent exposure only and a total of 43.3% presented with hearing loss due to combined noise and solvent exposure. Furthermore, the prevalence of hearing loss in the noise and solvent group was significantly ($p < 0.001$) higher than the other groups in 10 out of the 13 studies analysed with a pooled OR of 2.754. Of the 178 participants (total of all participants exposed to solvents), a total of 32 participants presented with auditory pathology as a result of exposure to solvents only. There was a significantly higher pooled odds of hearing loss in noise and solvent exposed group compared to solvent only group (Pooled OR=2.15, 95% CI: 1.24-3.72, p -value=0.006).

Conclusion: The findings revealed significantly higher odds of acquiring hearing loss when workers were exposed to a combination of solvents and noise as opposed to solvents only, motivating for its inclusion into hearing conservation programmes.

Keywords: Solvents, Solvent Induced Hearing Loss, Ototoxicity, Noise Induced Hearing Loss

¹ Under review by the journal of Noise and Health. Submitted to journal on the 28/11/2015.

Introduction

The body of evidence has been growing regarding not only the effects of chemical substances on the auditory system, but additionally on the combined auditory effects of chemicals and noise on hearing. Chemical substances alone or combined with high-level noise have recently become a major concern as a cause of occupational hearing loss.¹ Previously, noise was believed to be the only cause of hearing loss amongst workers in occupational settings,¹ however, recent studies have revealed that chemical substances which include solvents can also have ototoxic effects on the auditory system thus resulting in hearing loss.² Solvents are liquids that are used to dissolve substances, are colourless, have strong odours³ and have been noted in recent literature to induce auditory pathology. For the purpose of the review, the term “Solvent-Induced Hearing Loss” (SIHL) will be used, as solvents are ototoxic agents that cause hearing loss.^{3,4}

Workers within occupational settings are exposed to various work-related substances that may be hazardous to hearing such as asphyxiants, pesticides, metals and solvents. Morata & Little (2002)⁵ categorized solvents into two categories, high priority solvents such as toluene, xylene, styrene, *n*-hexane, trichloroethylene, lead and carbon monoxide and low priority solvents such as mercury, benzene, carbon disulphide and manganese.^{5, 1, 2} Both high and low priority solvents are commonly found in various industries and are considered to be ototoxic, neurotoxic and vestibulotoxic.⁶ A combination of solvents with noise can result in significant damage.

The relationship between solvents and noise is complex, particularly since the pathophysiology of SIHL is not fully understood.⁷ Available research findings regarding the effects of solvents on the auditory system of humans include: damage of sensory cells and nerve endings in the cochlear and in the auditory pathways, damage to the striavascularis which is the “fluid-producing cell layer on the outer wall of the cochlear duct,⁶ damage to the spiral ganglion cells, retro cochlear damage, vestibular damage and damage to Pillar and Deiters cells of the organ of Corti.⁷

Combined effects of noise and solvents on the auditory system may have a similar pathophysiology on the auditory system. Therefore, problems arise in adequately describing the combined effect, as it is not clear as to which specific event leads to auditory dysfunction; that is, does the auditory deficit occur due to noise exposure, solvent exposure or a combination of both. This information is important as data derived can contribute towards policy formulation and amending regulations. To date, there has been no shift towards including solvent exposure and monitoring into hearing conservation programmes (HCP’s) and medical surveillance programmes.

Three literature reviews were conducted previously regarding the combined effects of solvents and noise on auditory function. Fuente and McPherson (2012)³ provided a detailed discussion on hearing loss related to various solvents and their interaction with noise. Key findings of the study were that there are detrimental effects of solvents on the peripheral and central auditory system as well as various legislations available globally regarding

recommended exposure limits. Augusto and colleagues (2012)⁸ conducted a review and concluded that toluene exposure can affect auditory thresholds of workers. The study also found that the audiograms for Noise Induced Hearing Loss (NIHL) present similar to toluene induced hearing loss, thus making it difficult to differentiate between effects of noise and toluene combined and noise only.⁸ Cary, Clarke and Delic (1997)⁹ conducted a critical review of the literature to determine the effects of combined exposure to noise and toxic substances. The authors concluded that the studies were insufficient to determine any interaction between noise and solvents on hearing.⁹ All reviews were unable to make definitive conclusions regarding the interaction between noise and solvents on hearing. However, several more recent studies with larger sample sizes have since been published, permitting a more detailed review. The aim of the study was therefore, to conduct a systematic review and meta-analysis to assess the combined effect of solvents and noise on the auditory function of workers within various industrial settings.

Objective

To assess the combined effect of solvents and noise versus noise or solvents only on the auditory function of workers within various industrial settings.

Methods

Types of studies

Experimental, cross sectional studies comparing the audiometric results of groups of workers exposed to noise and solvents versus noise or solvents only.

Types of participants

Workers who were exposed to a combination of noise and solvents and noise or solvents only within various occupational settings. The workers were of either gender and consisted of ages ranging from 18-68 years old.

Types of interventions

Various audiological tests were conducted on workers who were exposed to noise and solvents.

Types of outcome measures:

Primary outcome

Hearing loss in workers exposed to solvents only vs. both noise and solvents.

Secondary outcomes

To identify secondary auditory dysfunctions, this included:

- Balance disorders
- Upper limit of hearing affected

Search methods for identification of studies:

Electronic searches

To perform a systematic review of the combined effects of solvents and noise on auditory function, a search was conducted for peer reviewed publications from 3 different databases. The databases used were Google scholar, Pubmed/Medline and Science direct/Scopus. The following search words were used on all 3 databases; “audiology OR solvents OR hearing loss OR industry”; “audiology OR solvents OR hearing loss”; “chemical ototoxicity”; “solvent induced hearing loss”; “industrial solvents and their effects on hearing”; “audiologist OR solvent induced hearing loss”, “audiology OR chemicals OR hearing loss OR industry”, and “xylene OR toluene OR hearing loss”.

Other additional searches

Full-text copies of each of these articles were obtained and read in detail by the review authors. In addition, the references of each article were reviewed to identify possible papers that were missed by the study search. This method of reviewing references of each article was used in order to cross check results and guarantee that all relevant articles were being used in the review.

Data collection and analysis:

Identifying studies

Full-text copies of each of these articles were found; all authors of this review paper independently reviewed the articles to ensure that all articles met the inclusion criteria. If one of the review authors were unclear, authors discussed the articles inclusion/exclusion together. Inclusion criteria included: (1) combined effect of solvents and noise, (2) studies conducted on human beings only, (3) use of audiological tests on participants. Once papers were screened, the abstracts of all records were retrieved to identify obvious exclusions. The reference list of each article was perused to identify possible studies that were missed by the study search. Figure 1 overleaf provides a summary of the number of studies retrieved from each database. A total of 13 studies were included into the review. The included studies are summarized in Appendix DD² and the characteristics of studies are summarized in Appendix EE.

² Appendices can be found from pages 160-174

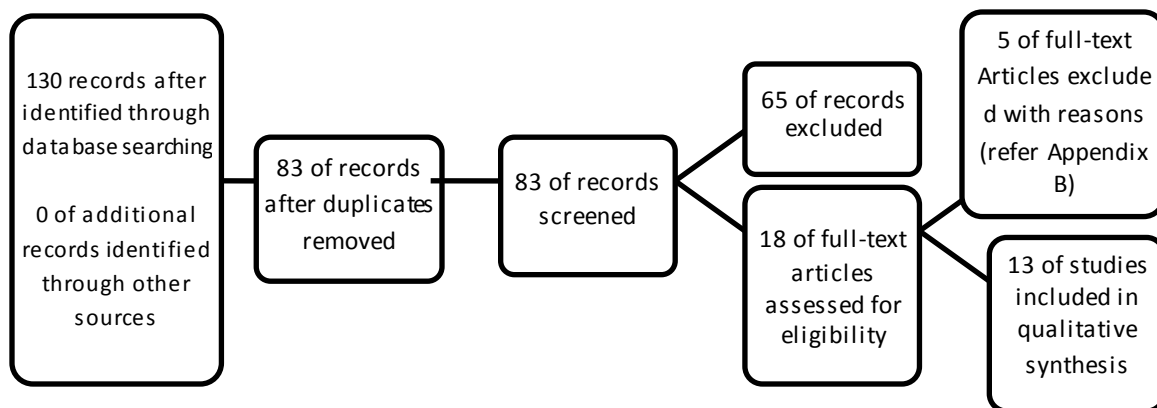


Figure 1 Database search results

Assessment of methodological quality

Heterogeneity was assessed in the selected studies by using the I^2 test. This test measures the extent to which the results of the studies were consistent. There was heterogeneity evident (high I^2 and significant heterogeneity).

Data extraction

The studies were categorized according to: year, country, article title, exposure, objective, design, results, conclusion and references (refer Appendix DD).

Data analysis

A meta-analysis was carried out and statistical heterogeneity was assessed. The fixed effect model was used and the odds ratio was calculated for statistical heterogeneity. The pooled estimates for dichotomous outcomes are reported as ORs with 95% CI. The primary comparison was risk of hearing loss in the noise and solvent exposed group versus noise only or solvents only exposed group. Other pair wise comparisons included solvent exposed groups versus a control group of no noise or solvent exposure. Heterogeneity of effect sizes was assessed using the I^2 statistic (measure of consistency across studies).¹⁰ As heterogeneity was present (i.e. $I^2 \geq 50\%$), the random effects method was used to estimate a pooled effect size (i.e. odds ratio). All analyses were performed using STATA version 13.0.¹¹ A p-value of <0.05 (two-tailed) was considered statistically significant except for the heterogeneity test where a p-value cut-off of less than 0.10 (one-tailed) was used.

Ethical considerations

Permission to conduct the review was granted by the Social and Human research Ethics committee (University of KwaZulu- Natal), protocol reference number HSS/0637/015M (refer Appendix FF).

Results

A total of 130 peer reviewed citations were comprehensively reviewed. Of these, 13 papers (3197 workers) were eligible for inclusion. See Appendix GG for a summary of participants' particulars. The included studies are summarized in Table 1 below. The participants' ages ranged from 18 to 68 years.

The studies had the following similarities: all selected studies were conducted on human participants, various audiological tests were conducted across all 13 studies; workers were exposed to a combination of noise and solvents, noise only or solvents only in all the studies; all studies were conducted in industries with the participants being workers based at the industries. Overview of the meta-analysis results will be presented according to the outcome measures.

Table 1 below describes the participants in the studies. The participants were divided into total number of participants recruited and the total number of participants that were used in the study (cases). The participants were further categorized into noise exposure only; solvent exposure only, combined noise and solvent exposure and control.

Table 1 Description of number of participants in studies

AUTHORS	Total	N only (tot)	S only (tot)	N+S (tot)	Control (tot)	N only (cases)	S only (cases)	N+S (cases)	Control (cases)
Barba et al. (2005)	172		82	52	38		20	16	4
Lobato et al. (2014)	198	42		57	99	7		3	
Hughes & Hunting (2013)	503	148	65	220	70	11	3	12	6
Rizk&Sharaf (2010)	140	50		60	30	9		14	1
Chang et al. (2003)	346	105		131	110	34		89	26
Metwally et al. (2012)	222	70		93	59	44		59	10
Botelho et al. (2009)	152	81		71		13		33	
Mohammadi et al. (2010)	337	173		164		60		113	
Chang et al. (2006)	174	58		58	58	26		50	3
Ikuharu et al. (2000)	54	19		23	12	5		12	3
Kim et al. (2005)	328	146	18	13	151	25	5	7	9
Prasher et al. (2005)	379	153	13	174	39		4	57	2
Schaper et al. (2008)	192	86		106		53		64	

Data synthesis:

Solvents and noise present in studies:

Ten articles (77%) contained exposure to noise and a mixture of solvents (methyl ethyl ketone, toluene, xylene and methyl isobutyl ketone), while 2 studies concentrated on exposure to noise and toluene only (15%) and 1 study concentrated only on exposure to noise and carbon disulphide (8%).

Types of audiometric tests used:

Table 2 below shows the various audiometric tests used in each study.

Table 2 Description of various audiometric tests used in studies

AUTHORS	TESTS USED
Barba et al. (2005)	Pure-tone audiometry
Lobato et al. (2014)	Pure-tone audiometry
Hughes & Hunting (2013)	Pure-tone audiometry
Rizk&Sharaf (2010)	Pure-tone audiometry
Chang et al. (2003)	Pure-tone audiometry
Metwally et al. (2012)	Pure-tone audiometry, Otoscopic examinations
Botelho et al. (2009)	AC, BC, SRT, SRS, Otoscopic examinations
Mohammadi et al. (2010)	Pure-tone audiometry
Chang et al. (2006)	Pure-tone audiometry, Otoscopic examinations
Ikuharu et al. (2000)	Pure-tone audiometry, High frequency audiometry
Kim et al. (2005)	Pure-tone audiometry
Prasher et al. (2005)	Pure-tone audiometry, OAEs, ABR, VNG and Posturography, Otoscopic examinations, Tympanometry, ART
Schaper et al. (2008)	Pure-tone audiometry

Abbreviations used: SRS (Speech Recognition Score)- VNG (Videonystagmography)- AC (Air Conduction)- BC (bone Conduction)- SRT (Speech Reception Testing)- OAEs (Oto-acoustic Emissions)- ABR (Auditory Brainstem Response)- ART (acoustic reflex threshold)

Primary outcomes:

Total prevalence of hearing loss:

Of the 3197 participants (total of all participants), 35% (n=912) presented with hearing loss as a result of noise exposure only; solvent exposure only and combined noise and solvent exposure.

Of the 1222 participants (total of all participants exposed to noise and solvents), 43.3% (n=529) presented with auditory pathology as a result of the combined exposure to noise and solvents. The data revealed that the prevalence of hearing loss in the noise and solvent group was significantly ($p < 0.001$) higher than the other groups in 10 out of the 13 studies analysed with Pooled OR of 2.754. Many studies did not have a solvent only group as solvents often coincide with noise in the working environment. Of the 178 participants (total of all participants exposed to solvents), a total of 32 participants presented with auditory pathology

as a result of exposure to solvents only. Figure 2 below shows the prevalence of hearing loss amongst the four groups for each of the included studies.

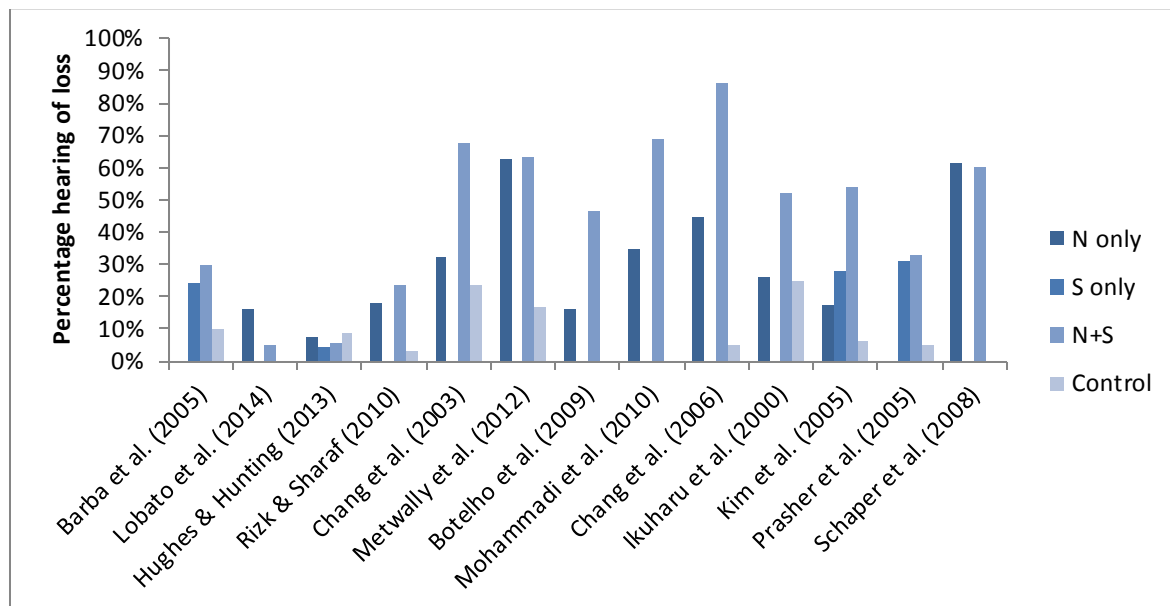


Figure 2 Prevalence of hearing loss amongst four groups

A total of 2285 participants did not present with any form of auditory pathology, despite their exposure to both solvents and noise or to solvents only or noise only. The combined estimate of the effects of solvents and noise versus noise only or solvents only obtained an odds ratio of 2.146 (see table 3 below). Table 3 and Figure 3 overleaf identifies that there is a significantly higher pooled odds of hearing loss in noise and solvent exposed group compared to solvent only exposed group (Pooled OR=2.15, 95% CI: 1.24-3.72, p-value=0.006). The large majority of participants exposed to noise and solvents showed the effects of hearing loss.

Table 3 Noise plus solvent vs. noise only

Heterogeneity chi-squared = 56.14 (d.f. = 10) p = 0.000				
I-squared (variation in OR attributable to heterogeneity)= 82.2%				
Estimate of between-study variance Tau-squared = 0.6659				
Test of OR=1 : z= 2.72 p = 0.006				
STUDY	OR	[95% Conf. Interval]		% Weight
Lobato et al. (2014)	0.278	0.067	1.147	6.61
Hughes & Hunting (2013)	0.719	0.308	1.675	9.22
Rizk & Sharaf (2010)	1.386	0.543	3.540	8.79
Chang et al. (2003)	4.425	2.555	7.664	10.56
Metwally et al. (2012)	1.025	0.539	1.950	10.16
Botelho et al. (2009)	4.543	2.136	9.661	9.65
Mohammadi et al. (2010)	4.173	2.647	6.579	10.92
Chang et al. (2006)	7.692	3.102	19.076	8.93
Schaper et al. (2008)	3.055	0.825	11.303	7.07
Kim et al. (2005)	5.647	1.748	18.237	7.68
Ikuharu et al. (2000)	0.949	0.529	1.700	10.42
D+L pooled OR	2.146	1.239	3.718	100.00

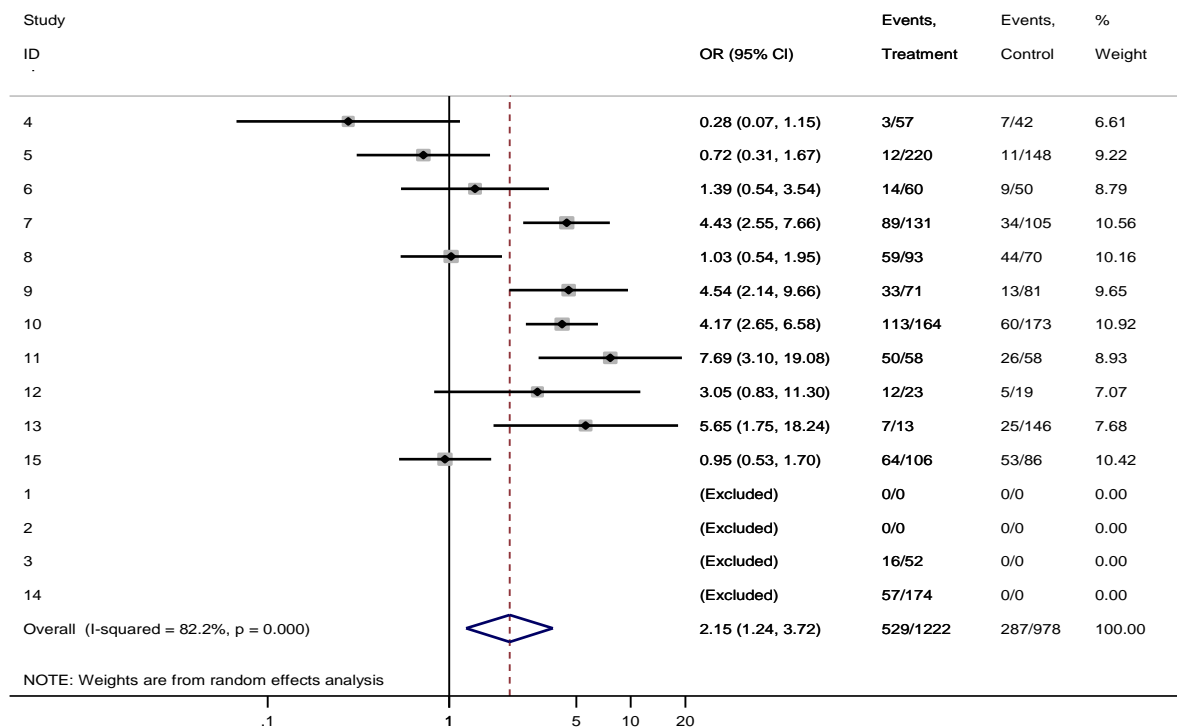


Figure 3 Noise plus solvent vs. noise only

Secondary outcomes:

In terms of secondary auditory dysfunctions, only one study reported on the effects of solvents and noise on the upper limit of hearing. Results of the study indicated a reduction of the upper limit of hearing which was the largest in the combined noise and solvent group.¹² With regards to balance disorders, Prasher, Al-Hajjal, Aylott, & Aksentijevic (2005)¹³ reported on the effects of solvents and noise on hearing and balance in workers. The audiological tests that were used to assess workers balance were VNG (Videonystagmography) and Posturography. Results revealed that 32% of workers in the solvents and noise group had abnormal posturography and VNG results. It was concluded that the effects of a mixture of solvents on the auditory system appears to occur both at the end organ level as well as in the nervous pathway.¹³

Discussion

The current review provided evidence of the effects of combined exposure of solvents and noise on the auditory system revealing a higher prevalence of hearing loss in the noise and solvent group than the other groups in 77% of the studies analysed. Kim, Park, HA, Jung, Paik, & Yang, (2005)¹⁴ reported in a study conducted on workers within the aviation industry that the prevalence of hearing loss in the noise and solvent group was higher than the other groups (54.9%) and similarly, Chang, Chen, Lien and Sung (2006) reported that the results revealed a higher prevalence of hearing loss in the toluene and noise group (86.2%) when compared to those exposed to noise only (44.8%). Both studies also revealed that the effect of

solvents on the auditory system appears to occur both at the end organ level as well as in the nervous pathway. ⁷

As reported in the studies, long term exposure to ototoxic solvents can have specific detrimental effects on the auditory system. These effects include: ototoxicity (substances that affect the structure and function of the inner ear and the neural pathways); neurotoxicity (substances that affect the central and peripheral nervous system) and vestibulotoxicity (substances that affect the structure and function of the vestibular organ).⁶ This triad of complications makes differential diagnosis of SIHL a challenging one as the symptoms are similar to other auditory pathologies such as NIHL. SIHL coupled with noise exposure, makes the relationship even more complex, particularly since so little is understood about the pathophysiology of SIHL. ¹⁵ Thus, research needs to further understand the route of exposure of solvents in order to address this issue, as noise exposure routes have been extensively researched.

Research findings indicate that the vapour particles of solvents are inhaled by workers, which are then absorbed via the respiratory tract. ¹ They can also be absorbed through the skin or exposed wound tissue, after which they translocate into the blood stream and travel through the body and affect cells where they interact with tissue that causes dysfunction in the body and certain organs. ^{16-18,3} In addition, once solvents are absorbed into the body via inhalation, the bodies metabolic system transforms the solvents into components that are present in blood and then excreted in urine. Solvents within the body have the potential to interact with various systems within the body, including the auditory system. The key elements with regard to adverse effects on the auditory system depend on the following three issues:

- the toxicity of the solvent,
- the rate of absorption and
- biotransformation (the process by which the “body metabolism transforms solvents into water soluble compounds”).^{13,15,19}

Research findings regarding the effects of solvents on the auditory system of humans include: damage of sensory cells and nerve endings in the cochlear and in the auditory pathways, damage to the stria vascularis which is the “fluid-producing cell layer on the outer wall of the cochlear duct”,⁶ damage to the spiral ganglion cells, retro cochlear damage, vestibular damage and damage to Pillar and Deiters cells of the organ of corti.^{7,14} Regarding inner ear damage, Campo and Maguin (2007)²⁰ reported that solvents infiltrate the cochlear and contaminate the tissue as opposed to contaminating the inner ear fluids. The mechanisms involved in auditory damage consist of the solvents travelling via the blood stream and through the stria vascularis, diffusing through the membranes of the cells constituting the outer sulcus, and impairing the organ of corti. ^{20,22} Campo, Lataye, Loquet, and Bonnet (2001) in Campo and Maguin (2007)²⁰ have observed disrupted membranes and concluded that solvents use the outer sulcus as the main route of intoxication to reach the outer hair cells (OHC’s). Research has shown that solvents then poison the hair cells, which results in the membranous structures becoming disorganised and causing hair cell death.⁶ In terms of specific OHC damage, the third row of OHC’s is thought to be most vulnerable as it is closest

to the stria vascularis,²⁰ after which the first and second rows are affected.^{3,23} Furthermore, solvents affect the OHC's in a specific area, i.e. the middle turn area, where middle frequencies are located^{22,24} and this is different from NIHL where the higher frequencies are generally affected.^{1,25}

As discussed by the above mentioned study, individual solvents are reported to cause SIHL²⁶ therefore, it is plausible to assume that a mixture of solvents will have a greater detrimental effect on the auditory system due to the cumulative effect. From the studies reviewed, participants from 11 out of the 13 studies were exposed to a mixture of solvents and these participants presented with hearing loss.

In terms of audiological tests that were conducted, all the studies used pure tone audiometry testing by assessing the frequency range of 125Hz to 8KHz whilst one study assessed the upper limit of hearing.¹² In the study by Ikuharu, Nobuyuki, Hiroichi, & Kazuhisa (2000),¹² it was observed that there was an occupational effect of noise and solvents on the upper limit of hearing in workers. The results had shown noise levels and solvent levels were within occupational exposure limits. There was no significant correlation found between upper limit of hearing and pure tones and organic solvent concentrations in the working environment. The reduction of upper limit of hearing was largest in the combined group.¹² Therefore, it is recommended that high frequency audiometry be used in the audiological assessment of workers as it can be used as an early indicator of SIHL.³ Another study included transient and distortion product otoacoustic emissions (OAEs), auditory brainstem potentials (ABR), VNG and posturography.¹³ The VNG investigations in this study revealed significant abnormalities to the vestibular organs in the group of workers exposed to solvents. More recently, researchers have confirmed that the balance system is affected by solvents. A study in 2011 by Zamyslowska-Szmytke, Politanski, & Sliwinska-Kowalska (2011)²⁷ discovered that balance abnormalities in solvent exposed workers indicated subclinical damage, mainly the central part of the vestibular system and body-movement coordination.²⁷ The wide variety of the tests indicates that different procedures are needed to detect solvent exposure in different parts of the auditory system. These varieties of tests enable the audiologist to differentiate between cochlear and retro cochlear pathologies, and can therefore, be used as a guideline for monitoring SIHL. Thus, audiologists need to consider the wide range of effects that solvent exposure could have on the auditory system and include a comprehensive test battery to monitor the affected workers.

The role of the Audiologist regarding SIHL

The role of the audiologist regarding SIHL is not clearly outlined in the studies mentioned. SIHL is a fairly new concern in the field of audiology and presents new challenges for audiologists. Many audiologists are not aware of SIHL, as most research results are published in occupational health journals, which are not typically reviewed by audiologists.⁴ Audiologists need to keep updated with new knowledge about hazards to hearing to be able to implement programs for such target groups. They also need to conduct further research within the SIHL field to expand the literature available, especially with regard to the mechanism and pathophysiology of ototoxic agents, as there is limited research in this area.

Results from research conducted can help policy makers establish threshold limit values. Audiologists also have a responsibility to provide information and awareness campaigns to management and stakeholders in order to promote the conservation of hearing among workers. This is particularly important, as certain industries expose their workers to varying levels of solvents depending on the task at hand, with audiologists needing to be aware of the risks to be able to discuss them with management. Audiologists are capable of conducting HCP for workers exposed to solvents. Johnson & Morata (2010)¹ recommend that adjustments need to be made to the HCP in combined chemical and noise industries. These adjustments include: taking chemical exposures into account when monitoring air exposures, assessing workers who are exposed to chemicals more regularly, as well as using different methods for controlling workers exposures to chemicals. ¹ Researchers also suggested that the HCP needs to include short-interval audiometric evaluations, high frequency audiometry, and efficient hearing protection devices (HPD).⁷

Future research needs

Future studies need to focus on a longitudinal study design as this will increase the sample size and thus improve generalization. One of the main limitations noted in the studies was small sample sizes thus minimal conclusions could be drawn from the studies.^{13,14,28,29} In addition, it is worthwhile for research studies to vary the study design from a cross sectional to a longitudinal design as the studies mentioned used a cross-sectional design and the main limitation of this design is that it cannot establish causal relations.³⁰ Using a longitudinal design will allow the researcher to assess ototoxic effects effectively, as literature reveals that ototoxic effects occurs over a period of time.³¹ Future research needs to focus on stricter inclusion and exclusion criteria. Researchers did not impose the age limit on their participants in order to control for age effects on hearing. The results could be confounded due to some workers being above the age of 60 years when typically presbycusis sets in,¹² therefore imposing age as a strict inclusion criteria is necessary. Furthermore, workers within industries may present with variables that may influence the cause and effect relationship (such as factors that affect their hearing, e.g. smoking) regarding noise and solvent exposure on their auditory system, which some studies did not consider, further highlighting the need for stringent inclusion and exclusion participant criteria. ¹² Cumulative dose of exposure is the total dose from conducting repeated air measurements over a period of time.⁷ The cumulative dose of exposure is relevant; as it could determine current threshold limits for solvent exposure.⁷ There was a lack of information regarding previous solvent exposure levels of workers and this measure was not calculated for all studies. Further research studies conducted should attempt to obtain matching sample size numbers in order for appropriate conclusions to be made. Some studies had unmatched numbers across groups, thus only limited conclusions could be drawn from the studies.¹³ It is recommended that personal dosimetry measurements be conducted for both noise and air measurements as this will allow for more specific analysis of results per worker. There was a lack of individual samplings (dosimeter and air measurements) of toluene from participants during solvent exposure measurements.²⁹ Furthermore, literature states that once solvents are absorbed into the body via inhalation, the bodies metabolic system transforms the solvents into components that are present in blood and then excreted in urine. This demonstrates the need to be able to

adequately monitor workers exposed to solvents by monitoring their metabolites (blood and urine) for traces that have been in their system as well as the solvent concentrations in the air.¹³ The limitation across all of the reviews mentioned was that there was no testing of urine and blood of the workers, therefore, future research projects should include these tests as it could add validity to research findings.

Conclusion

The findings of the systematic review and meta-analysis concluded that there are significantly higher odds of acquiring hearing loss when workers are exposed to a combination of solvents and noise as opposed to solvents only. Globally, there is limited research available on noise and solvent interactions and their effects on hearing. Furthermore, there are only a few comparative studies with varied conclusions, requiring further investigation into the effects of the combined exposure on hearing. Most industries do not control the levels of solvents that they use and do not take into consideration regulations concerning the use of ventilation systems and the provision of masks, gloves or other personal protective equipment which could harm workers, therefore making workers more susceptible to detrimental effects on the auditory system as a result of combined solvent exposure.

The challenge for the audiologist is that in an occupational environment, since the workers are usually exposed to mixtures of substances, it is not easy to evaluate the effects associated with exposure to a specific chemical. In addition, most threshold limit values are established for a single solvent; however, industries are often composed of several solvents simultaneously. Thus, developed occupational threshold limits are currently based on isolated workplace hazards that are not adequate for protecting workers who may be exposed to multiple solvents in industries coincidentally and sequentially.² Therefore, recommendations emerging from the studies regarding SIHL for audiologists include:

- Prioritizing personal solvent monitoring³¹
- Evaluating personal protective equipment use³¹
- Appropriate recording: Health results of workers should be recorded and checked regularly in order to detect early changes at individual and collective levels²
- Risk management measures aimed at reducing exposure to ototoxic substances should be encouraged³²
- Ototoxicity monitoring that should be made a part of occupational health-screening activities³²
- Suitable scientific investigations into ototoxic properties should be encouraged such as longitudinal epidemiological studies.³²

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4.3. AIM TWO:

To profile the audiological results of a group of workers exposed to solvents in high and low noise level factories in KZN.

4.3.1. Objective one:

To profile the noise measurements, air measurements and audiometric results of factory workers within paint and shoes factories exposed to varied types and levels of solvents at three intervals over a period of six months.

The researcher conducted noise measurements at the industry using a Personal Dosimeter for noise readings in various areas of the factory to obtain overall readings for workers. The measurement time intervals were chosen to best represent the type and duration of the noise present at different locations in order for noise assessments to be adequately covered (SANS, 2004). Measurements of the noise levels (dB) were taken over short durations on three different occasions over a period of six months. Both LAeq and LApeak levels including levels over the spectral range were recorded. These levels were compared to standardized data (≥ 85 dB) obtained from the SANS document for noise (SANS, 2004).

The measurements showed noise levels ranging from 75 dB to 91 dB among the study areas. Figure 10 below represents the average/mean noise levels across the three industries over the three phases of the study. The noise levels were 88 dB (range: 83 dB - 91 dB) in industry one, 83 dB (range: 80 dB- 86 dB) in industry two and 77 dB (range: 75 dB- 80 dB) in the third industry. Industry one was exposed to higher noise levels than industry two, but industry two and three were exposed to levels within the permissible limits (≥ 85 dB).

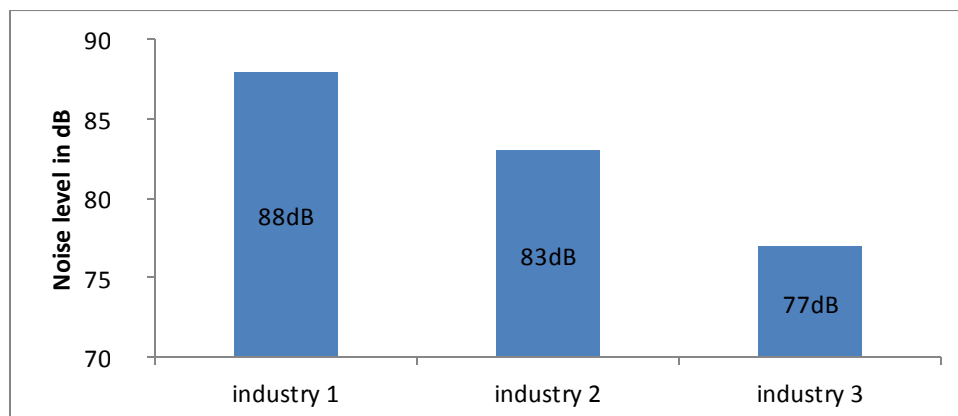


Figure 10. The mean noise measurement results across industries.

Figure 11 below indicates the various solvents with their mean measurements over three phases that were present in the industries. Solvents that were present in the industries included toluene, dichloromethane, xylene, trimethyl benzenes, n-hexane, acetone, aliphatic hydrocarbons (as white spirits) and benzene. Toluene was the highest solvent present across all three industries and followed by white spirits which was the second highest. Other high solvents that were present include xylene and acetone.

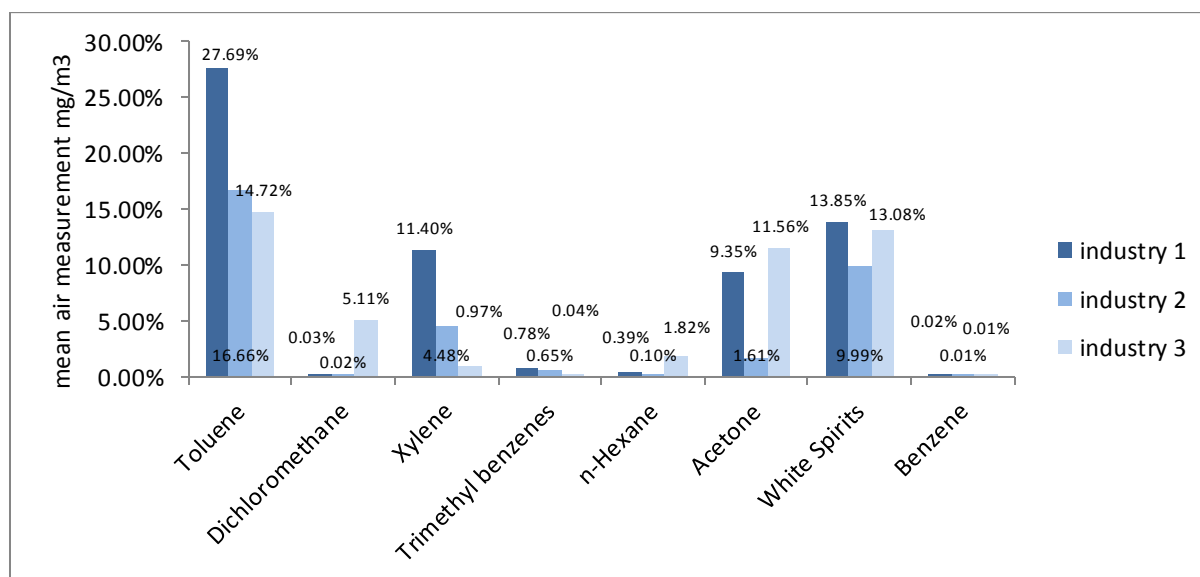


Figure 11. The solvents present in the industries with their mean measurement over 3 phases.

Table 8 overleaf represents the air measurement results per phase per industry, as well as their exposure limits. Results indicated that with the exception of the single high result shown (1.21mg/m³) in industry one (see table 8) and the one other result in excess of the 50% additive OEL (0.61mg/m³) in industry two, all of the results found were low and in compliance with recommended additive exposure limits for mixed Volatile organic compounds (VOC's).

Table 8 overleaf further displays the presence of Dichloromethane (a toxic solvent) in industry three with a mean of 5.11 mg/m³. Samples two, 10 and 17 (in red) also contained high levels of MEK (a toxic solvent) for industry three; this compound was not identified at the other factories. Other VOC's were present in low levels in many of the samples but were not included in the main calculated report due to complexity and the low levels present. All simple straight chain aliphatic were added to the white spirit result and calculated as a total hydrocarbon and white spirit result as these were generally relevant in volume. This is normal practice as there is no OEL for many of the individual compounds (Hills, personal communication, 2014).

Table 8

Air Measurement Results per Phase per Industry

VOC'S RESULTS														
	OEL				188	350	435	123	70	1780	575	1.6		UCL
Date	Sample #	Person / Position	Time	Volume	Toluene	Dichloromethane	Xylene	Trimethyl benzenes	n-Hexane	Acetone	Aliphatic hydrocarbons as White Spirits	Benzene	Exposure Index	
			(mins)	(l)	(mg/m3)	(mg/m3)	(mg/m3)	(mg/m3)	(mg/m3)	(mg/m3)	(mg/m3)	(mg/m3)		
7-Apr	3	Industry 1	370	38	2.98	0.03	1.76	0.75	0.08	0.17	8.67	0.01	0.05	0.16
8-Jul	11		391	38	2.49	0.03	3.31	0.19	0.27	4.27	4.95	0.01	0.04	0.15
12-Oct	20		408	39	180.50	0.03	19.71	1.28	0.05	0.03	17.49	0.09	1.10	1.21
7-Apr	4	Industry 1	366	40	2.57	0.02	2.65	1.20	0.07	0.57	5.04	0.01	0.05	0.15
8-Jul	12		398	40	13.29	0.02	24.04	0.34	1.47	41.59	22.76	0.00	0.22	0.32
12-Oct	18	Industry 1	405	46	18.17	0.02	38.71	2.05	1.13	28.18	47.27	0.04	0.34	0.45
8-Apr	5	Industry 1	367	37	0.74	0.03	0.49	0.20	0.03	0.00	2.28	0.01	0.01	0.12
8-Apr	6		367	38	0.76	0.03	0.50	0.23	0.03	0.00	2.31	0.01	0.02	0.12
8-Apr	7	Industry 2	393	37	20.09	0.03	2.18	1.30	0.00	0.00	20.67	0.01	0.17	0.27
9-Jul	13		361	41	4.08	0.02	1.65	0.63	0.02	0.04	6.44	0.00	0.05	0.15
13-Oct	21		435	44	79.13	0.02	10.18	0.74	0.03	0.02	11.32	0.05	0.50	0.61
8-Apr	8	Industry 2	395	45	1.88	0.02	0.30	0.14	0.00	0.00	1.92	0.00	0.02	0.12
9-Jul	15		360	44	0.32	0.02	0.24	0.16	0.02	0.02	0.73	0.00	0.01	0.11
9-Jul	14	Industry 2	362	35	2.32	0.03	1.30	0.54	0.02	0.06	4.49	0.01	0.03	0.14
13-Oct	20		435	44	8.81	0.02	15.52	1.06	0.63	11.16	24.28	0.02	0.16	0.27
7-Apr	1	Industry 3	372	44	11.16	0.77	0.16	0.01	0.91	7.15	21.79	0.02	0.13	0.24
8-Jul	9		401	43	27.94	13.67	3.49	0.15	1.69	0.33	8.85	0.00	0.24	0.35
12-Oct	16		433	41	1.51	1.20	0.01	0.01	2.71	3.44	2.05	0.01	0.06	0.17
7-Apr	2	Industry 3	370	34	23.23	0.76	1.00	0.02	1.39	19.3	38.13	0.03	0.24	0.35
8-Jul	10		402	47	18.31	11.21	1.11	0.06	3.96	0.61	1.27	0.00	0.19	0.30
12-Oct	17		428	42	6.15	3.07	0.04	0.01	0.24	38.55	6.40	0.01	0.09	0.19

Key: -Sample result Below Detectable Limit (BDL) - detection limit used in calculation- Identifies over exposure to total VOC's- Identifies exposure in excess of 50% of the additive OEL - reason for concern

Regarding the pure tone audiometric results, findings illustrated in Figure 12 overleaf displays the air conduction pure tone thresholds (250-12000 Hz) for the right and left ears for workers exposed to solvents and noise. The results are categorized into low frequencies (250Hz & 500Hz), mid frequencies (1000Hz) and high frequencies (2000-12000 Hz). Pure tone threshold results revealed that all workers experienced normal hearing (equal or better than 25 dBHL) in the low-mid frequencies across all three phases (100%). All the workers experienced hearing loss in the high frequencies, particularly at 12KHz, with a mean of 45dBHL across all the phases. Two of the workers (worker 2 & 3) did not experience hearing loss at 12KHz in the first and second phase of testing, however, developed hearing loss in phase three of testing after six months. This could be indicative of progression of hearing loss over time.

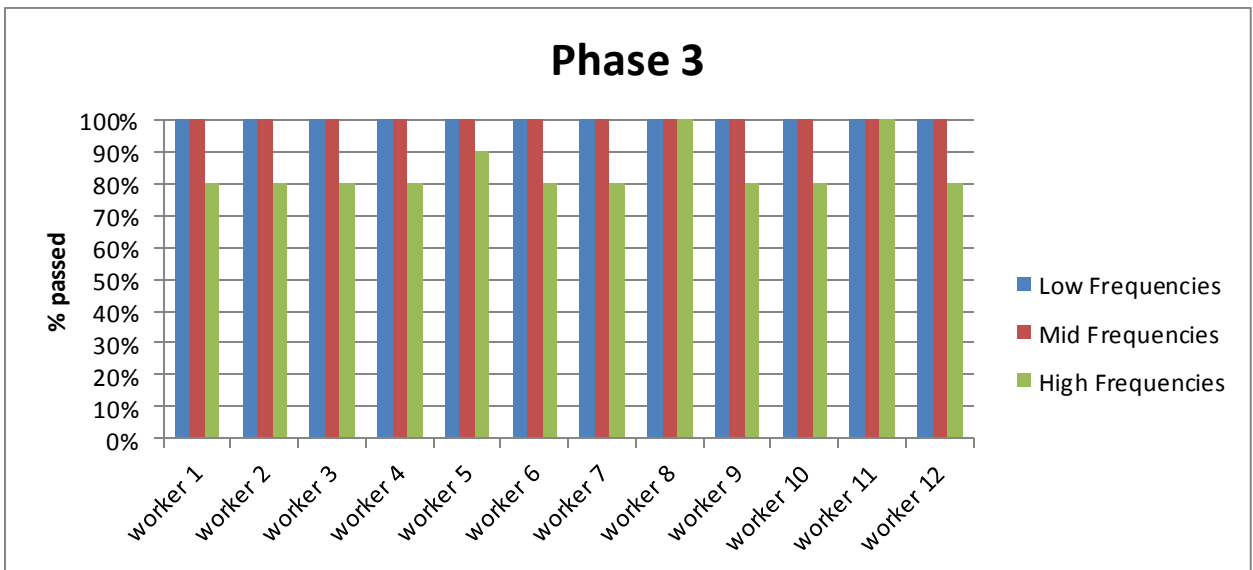
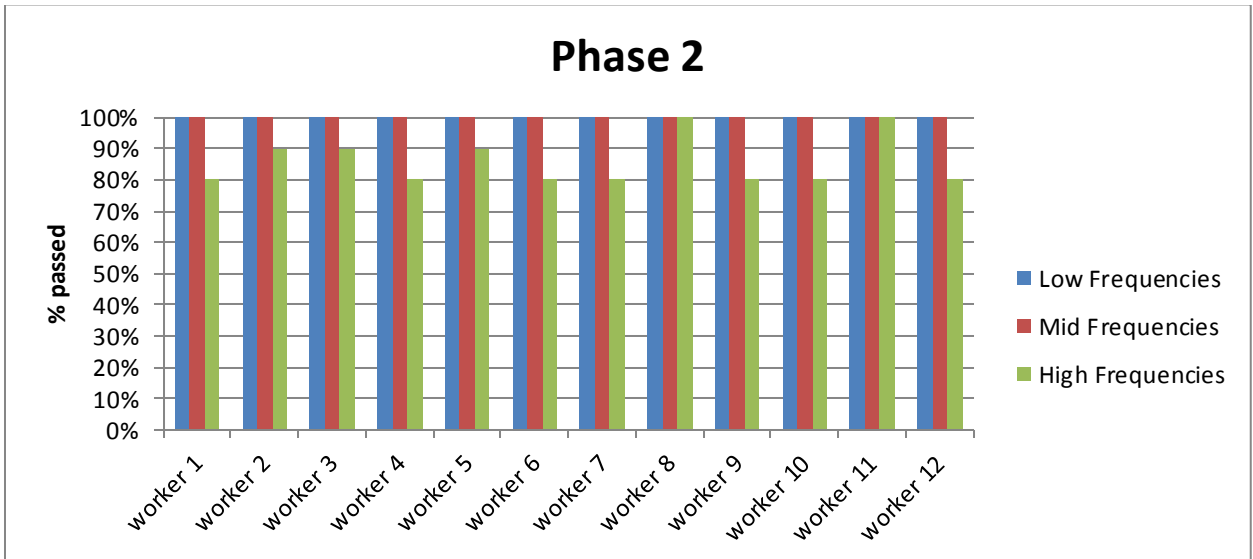
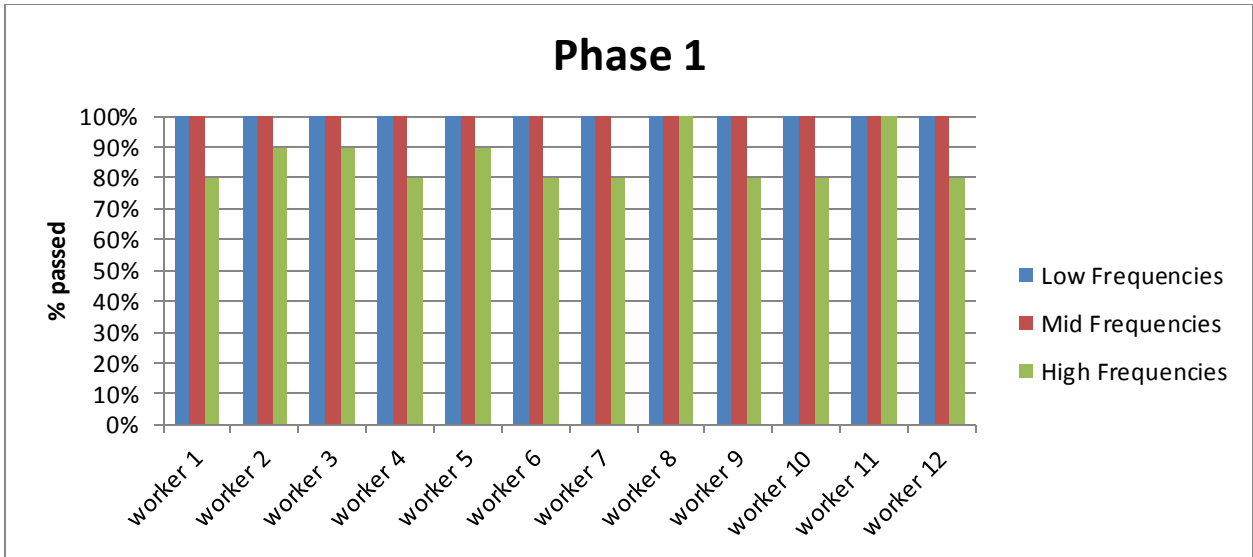


Figure 12. Audiometric results of pure tone testing for right and left ears combined according to low frequencies, mid frequencies and high frequencies per phase.

Table 9 below represents the mean OAE results (750-8000 Hz) for the right and left ears for workers exposed to solvents and noise. Results for DPOAEs revealed that all workers had reduced amplitudes across all three phases with the exception of one pass result at one phase for one worker. It is interesting to note that the low frequencies were also affected amongst most of the workers.

Table 9

Mean OAE Results

DP amplitude value				
	Phase one	Phase two	Phase three	Mean /average
Worker 1	4dB	-3dB	-1dB	0dB
Worker 2	2dB	-1dB	-2dB	-0.3dB
Worker 3	-13dB	-10dB	-11dB	-11dB
Worker 4	-7dB	-11dB	-8dB	-9dB
Worker 5	-1dB	8dB	4dB	3dB
Worker 6	-11dB	-10dB	-9dB	-10dB
Worker 7	-9dB	-6dB	-10dB	-8dB
Worker 8	-7dB	-2dB	-6dB	-5dB
Worker 9	-5dB	-10dB	-8dB	-8dB
Worker 10	-8dB	-6dB	-8dB	-7dB
Worker 11	-15dB	-3dB	-12dB	-10dB
Worker 12	-9dB	2dB	1dB	-2dB

The results obtained indicated that industry one had the highest noise levels of 88dB (see figure 12) as well as the highest mean levels for all solvents (0.34mg/m³) (see figure 13) when compared to industry two and three. When audiometric results of participants from industry one were compared to industry two and three to determine if there was a greater auditory deficit in the workers exposed to higher solvents and noise levels, no significant results could be obtained due to the small sample size.

4.3.2. Objective two:

To compare the pure tone thresholds to DPOAE amplitudes in a group of workers exposed to solvents in order to determine the possibility of sub-clinical hearing loss.

Pure tone audiometric thresholds of low frequency (500Hz), mid frequency (1000Hz) and high frequency (12000Hz) and the corresponding geometric means of low frequency (750Hz), mid

frequency (1000Hz) and high frequency (8000Hz) for DPOAEs were utilised and considered for statistical analysis. This was done due to the fact that although one cannot accurately relate the pure tone frequencies to the stimulus frequency, in most cases the slight difference between pure tone and distortion product stimulus frequency will be inconsequential as cochlea function is the same for both.

Two by two Contingency tables depicting the correlation between both the tests were generated and are displayed in tables 10-15 below. These tables reflect the measures of agreement between pure tone audiometry and DPOAEs together with the McNemar statistical value and the corresponding *p*-value.

Table 10

The Results Obtained At the High Frequency Range of 12000Hz/8000Hz for Workers Right Ears

Right 12000Hz/8000Hz Cross tabulation				
Count				
		DPOAEs 8000		Total
		F	P	
Pure Tones	F 12000	17	8	25
	P	4	7	11
Total		21	15	36

Chi-Square Tests		
	Value	Exact Sig. (2-sided)
McNemar Test		.388
N of Valid Cases	36	

F= FAIL P=PASS

According to the analysis at 12000Hz/8000Hz for the right ears, both pure tone audiometry and DPOAEs could equally detect normal responses in 4 (11%) out of the 36 observations. Pure tone audiometry detected 11 (47%) out of 36 observations as abnormal whereas DPOAEs detected this as a normal response. Both pure tone audiometry and DPOAEs detected 8 (22%) out of 36 observations as abnormal responses and DPOAEs detected 25 (69%) out of 36 observations as abnormal which pure tone audiometry detected as normal responses. The level of agreement between the two tests does not differ significantly in the observation of normal and abnormal responses being detected, as the *p*-value=0.38. This indicates that DPOAEs and pure tone audiometry was fairly equally sensitive in detecting abnormal and normal responses at 12000Hz/8000Hz.

Table 11

The Results Obtained At the High Frequency Range of 12000Hz/8000Hz for Workers Left Ears

Left 12000Hz/8000Hz Cross tabulation				
Count				
		DPOAEs 8000		Total
		F	P	
Pure Tones	F 12000	24	4	28
	P	2	6	8
Total		26	10	36

F= FAIL P= PASS

Chi-Square Tests		
	Value	Exact Sig. (2-sided)
McNemar Test		.687 ^a
N of Valid Cases	36	

According to the analysis at 12000Hz/8000Hz for the left ears, both pure tone audiometry and DPOAEs could equally detect normal responses in 2 (6%) out of the 36 observations. Pure tone audiometry detected 24 (67%) out of 36 observations as abnormal whereas DPOAEs detected this as a normal response. Both pure tone audiometry and DPOAEs detected 4 (11%) out of 36 observations as abnormal responses and DPOAEs detected 6 (17%) out of 36 observations as abnormal which pure tone audiometry detected as normal responses. The level of agreement between the two tests does not differ significantly in the observation of normal and abnormal responses being detected, as the p-value=0.68. This indicates that DPOAEs and pure tone audiometry was fairly equally sensitive in detecting normal and abnormal responses at 12000Hz/8000Hz.

Table 12

The Results Obtained At the Mid Frequency Range of 1000Hz/1000Hz for Workers Right Ears

Right 1000Hz/1000Hz Cross tabulation				
Count				
		DPOAEs 1000		Total
		F	P	
Pure Tones	P 1000	9	27	36
	F			
Total		9	27	36

F= FAIL P= PASS

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
McNemar-Bowker Test	.	.	. ^a
N of Valid Cases	36		

According to the analysis at 1000Hz/1000Hz for the right ear, both pure tone audiometry and DPOAEs could equally detect normal responses in 9 (25%) out of the 36 observations. DPOAEs detected 27 (75%) out of 36 observations as abnormal which pure tone audiometry detected as normal responses. The level of agreement between the two tests did not differ significantly in the observation of normal and abnormal responses being detected as both tests classified everything as normal

therefore a two by two table could not be obtained and there is no statistic and p-value (Matthews, personal communication, 2015). This indicates that DPOAEs and pure tone audiometry was fairly equally sensitive in detecting normal and abnormal responses at 1000Hz/1000Hz.

Table 13

The Results Obtained At the Mid Frequency Range of 1000Hz/1000Hz for Workers Left Ears

Left 1000Hz/1000Hz Cross tabulation					Chi-Square Tests			
Count		DPAOE's 1000		Total	Value	df	Asymptotic Significance (2-sided)	
Pure Tones	P	F	P					
Pure Tones	P 1000	19	17	36	.	.	.	^a
Total		19	17	36				
					N of Valid Cases	36		

F= FAIL	P= PASS
---------	---------

According to the analysis at 1000Hz/1000Hz for the left ear, both pure tone audiometry and DPOAEs could equally detect normal responses in 19 (53%) out of the 36 observations. DPOAEs detected 17 (47%) out of 36 observations as abnormal which pure tone audiometry detected as normal responses. The level of agreement between the two tests did not differ significantly in the observation of normal and abnormal responses being detected as both tests classified everything as normal therefore a two by two table could not be obtained and there is no statistic and p-value (Matthews, personal communication, 2015). This indicates that DPOAEs and pure tone audiometry was fairly equally sensitive in detecting normal and abnormal responses at 1000Hz/1000Hz.

Table 14

The Results Obtained At the Low Frequency Range of 500Hz/750Hz for Workers Right Ears

Right 500Hz/750Hz Cross tabulation					Chi-Square Tests			
Count		DPOAEs 750		Total	Value	df	Asymptotic Significance (2-sided)	
Pure Tones	P	F	P					
Pure Tones	P 500	23	13	36	.	.	.	^a
Total		23	13	36				
					N of Valid Cases	36		

F= FAIL	P= PASS
---------	---------

According to the analysis at 500Hz/750Hz for the right ear, both pure tone audiometry and DPOAEs could equally detect normal responses in 23 (64%) out of the 36 observations. DPOAEs detected 13 (36%) out of 36 observations as abnormal which pure tone audiometry detected as normal responses. The level of agreement between the two tests did not differ significantly in the observation of normal and abnormal responses being detected as both tests classified everything as normal therefore a two by two table could not be obtained and there is no statistic and p-value (Matthews, personal communication, 2015). This indicates that DPOAEs and pure tone audiometry was fairly equally sensitive in detecting normal and abnormal responses at 500Hz/750Hz.

Table 15

The Results Obtained At the Low Frequency Range of 500Hz/750Hz for Workers Left Ears

Left 500Hz/750Hz Cross tabulation				
Count				
		DPOAEs 750		Total
		F	P	
Pure Tones	P 500	28	8	36
Total		28	8	36

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
McNemar-Bowker Test	.	.	. ^a
N of Valid Cases	36		

F= FAIL P= PASS

According to the analysis at 500Hz/750Hz for the left ear, both pure tone audiometry and DPOAEs could equally detect normal responses in 28 (78%) out of the 36 observations. DPOAEs detected 8 (22%) out of 36 observations as abnormal which pure tone audiometry detected as normal responses. The level of agreement between the two tests did not differ significantly in the observation of normal and abnormal responses being detected as both tests classified everything as normal therefore a two by two table could not be obtained and there is no statistic and p-value (Matthews, personal communication, 2015). This indicates that DPOAEs and pure tone audiometry was fairly equally sensitive in detecting normal and abnormal responses at 500Hz/750Hz.

The above statistics indicated that there were no significant differences ($p=0.68$ and $p=0.38$) between pure tone audiometry and DPOAEs in detecting normal and abnormal responses for both ears across the low, mid and high frequency ranges of 500Hz, 1000Hz and 12000Hz; and the geometric means of 750Hz, 1000Hz and 8000Hz. **This indicated that no participants presented with a sub-clinical hearing loss as those that presented with abnormal OAE results also presented with abnormal pure tone audiometric results. The results were comparable in that those that presented with hearing loss in the high frequencies also presented with reduced DPOAE amplitude.**

Frequency patterns

Time series data was obtained using frequency patterns for Pure Tones and DPOAEs for the lowest, mid and highest frequencies of both ears. The workers were observed at phase 1, phase 2 and phase 3. The figures 13-18 below represent the type of test, the frequency, the different phases and the percentage pass of workers auditory function.

The results obtained at the low frequency range of 500Hz for pure tones for workers right and left ears revealed that there was no change over time regarding deterioration of workers hearing.

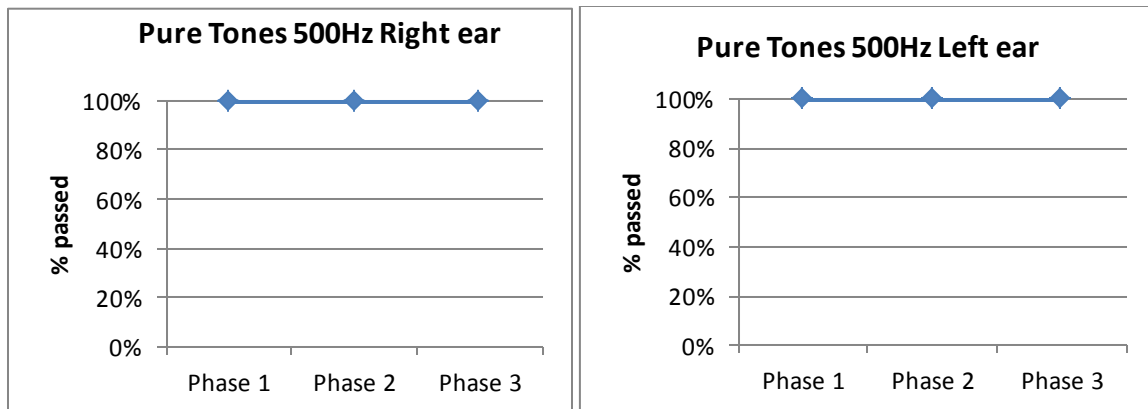


Figure 13. The results obtained at the low frequency range of 500Hz for pure tones for workers right and left ears.

The results obtained at the mid frequency range of 1000Hz for pure tones for workers right and left ears revealed that there was no change over time regarding deterioration of workers hearing.

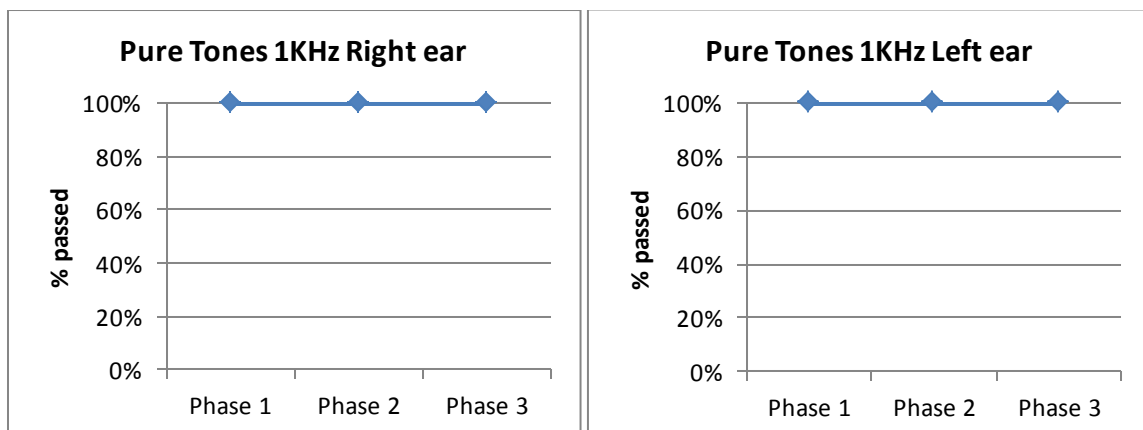


Figure 14. The results obtained at the mid frequency range of 1000Hz for pure tones for workers right and left ears.

The results obtained at the high frequency range of 12000Hz for pure tones for workers right and left ears revealed that there was a minor shift over time regarding deterioration of workers hearing.

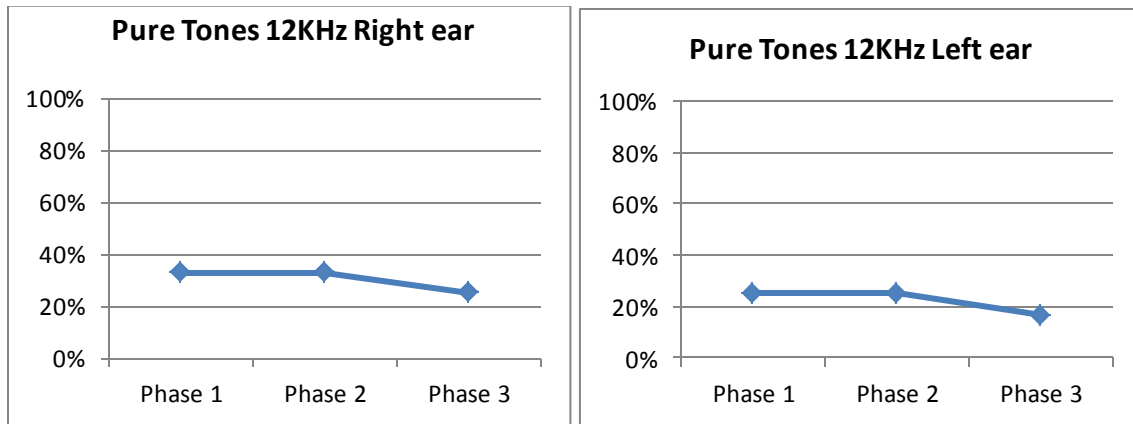


Figure 15. The results obtained at the high frequency range of 12000Hz for pure tones for workers right and left ears.

The results obtained at the low frequency range of 750Hz for DPOAEs for workers right and left ears revealed that there was a negative shift over time regarding deterioration of workers hearing.

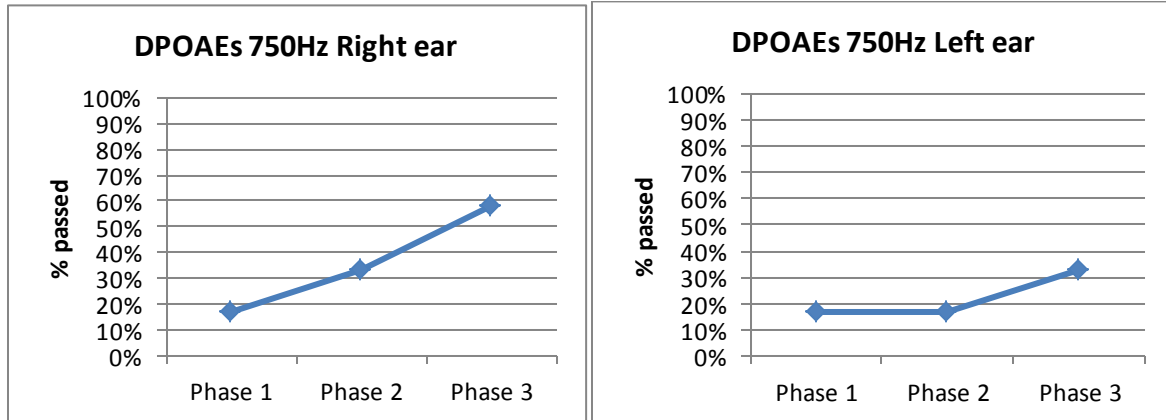


Figure 16. The results obtained at the low frequency range of 750Hz for DPOAEs for workers right and left ears.

The results obtained at the mid frequency range of 1000Hz for DPOAEs for workers right and left ears revealed that there was a negative shift over time regarding deterioration of workers hearing.

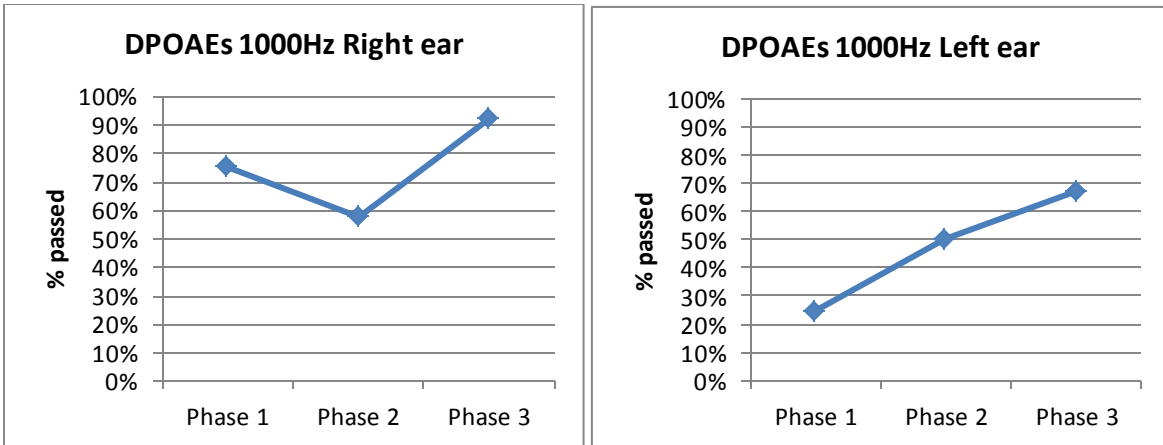


Figure 17. The results obtained at the mid frequency range of 1000Hz for DPOAEs for workers right and left ears.

The results obtained at the high frequency range of 8000Hz for DPOAEs for workers right and left ears revealed that there was a minor shift over time regarding deterioration of workers hearing.

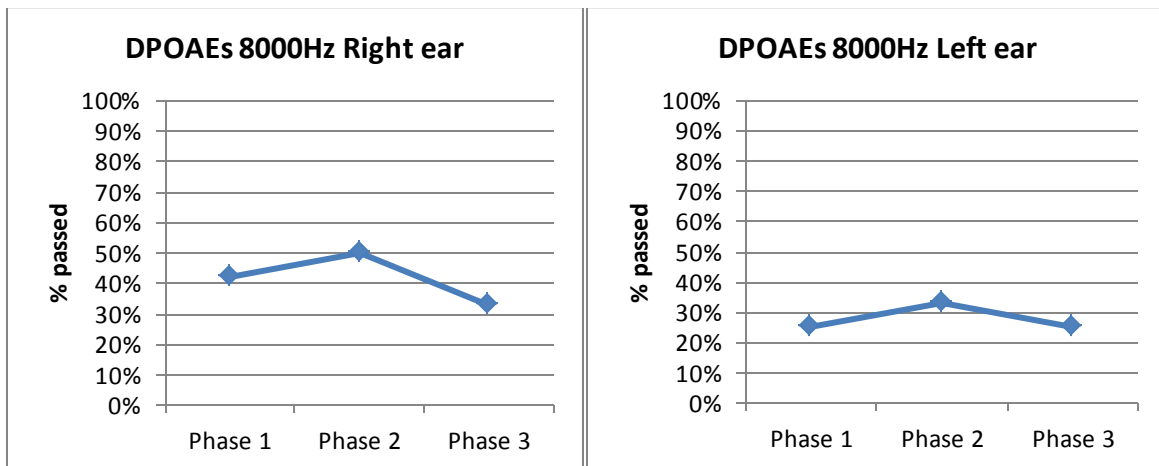


Figure 18. The results obtained at the high frequency range of 8000Hz for DPOAEs for workers right and left ears.

The results above revealed no significant results for change over time regarding pure tones and DPOAEs and workers hearing function. The sample of 12 workers (24 ears) was too small to reveal any significant results. However, the data does reveal that at the higher frequencies there is a decline in auditory function.

4.3.3. Objective three:

To describe the symptoms that workers associated to their exposure to solvents.

Figure 19 below represents the results from the case history findings. The symptoms experienced from solvent exposure were categorized into headaches, dizziness, blurry eyes and breathing problems. Results revealed that the highest complaint reported was blurry eyes (58%) and the least complaints were for symptoms of dizziness (25%).

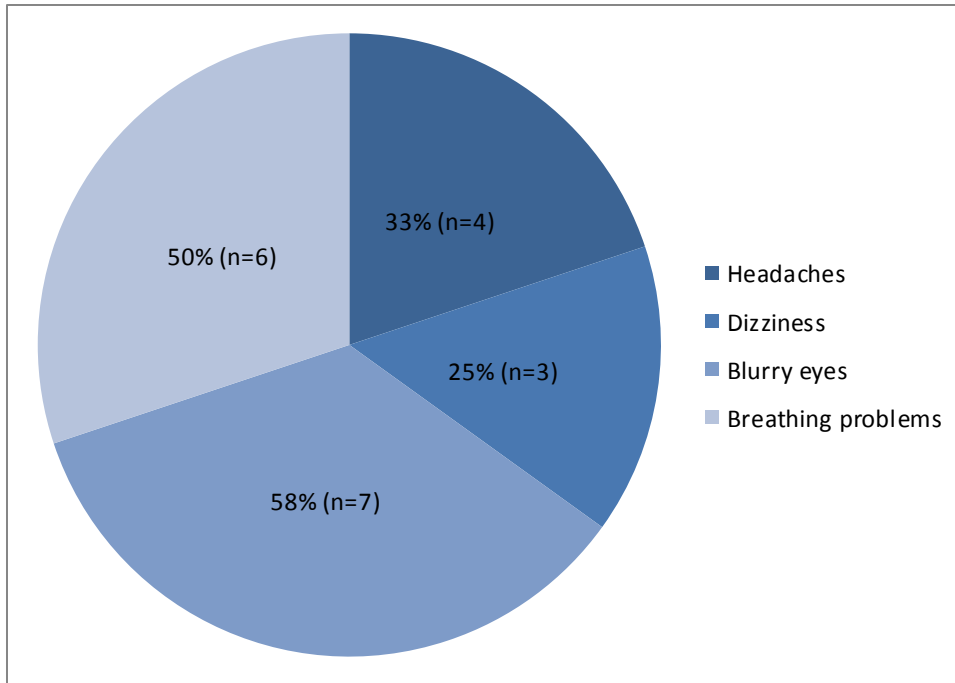


Figure 19. The symptoms experienced from solvent exposure.

In summary, the findings of aim two reveal that in terms of noise levels, industry one was exposed to high noise levels (by 3dB) and industry two and three were exposed to levels within the permissible limits. For solvent levels, toluene was the highest solvent present across all three industries followed by white spirits. Other high solvents that were present include xylene and acetone. Results indicated that with the exception of two high results shown in industry one and in industry two, all of the air measurement results were found to be low and within limits. The present study revealed that pure tone threshold results indicated that all workers experienced normal hearing in the low-mid frequencies across all three phases. However, there was evidence of hearing loss in the high frequencies, particularly at 12 KHz, across all the phases. This loss occurred despite the fact that noise and solvent levels were lower than the permissible levels. Two of the workers did not experience hearing loss at 12 KHz in the first and second phase of testing, however, developed hearing loss in phase three of testing after six months. This could be indicative of progression of hearing loss over time. There were no significant differences ($p=0.68$ and $p=0.38$) between pure tone audiometry and DPOAEs in detecting normal and abnormal responses of auditory function for both ears across all frequency ranges. There were no changes over time regarding pure tones and DPOAEs and workers hearing function, however, it must be noted that the sample of 12 workers (24 ears) was too small to reveal

any significant results. However, the results obtained at the high frequency range of 12000Hz for pure tones for workers right and left ears revealed that there was a minor shift over time regarding deterioration of workers hearing; thus, the hearing of workers need to be monitored more closely at this frequency. The symptoms experienced from solvent exposure were categorized into headaches, dizziness, blurry eyes and breathing problems. Results revealed that the highest complaint reported was blurry eyes and the least complaints were for symptoms of dizziness.

4.3.4. Discussion

Hearing loss in industries has generally been associated with noise exposure only; however, in recent years there is a growing awareness that solvents within industries can also have an adverse effect on the auditory function of workers. Both animal and human studies have reported that solvents, together with noise, results in auditory damage (Unlu et al., 2014). The present study revealed that there was elevated hearing loss in the high frequencies for workers who were exposed to solvents. This loss occurred despite the fact that noise and solvent levels were lower than the permissible levels. Similar to previous studies, the present study suggests that exposure limits for solvents are not sufficient to protect workers from SIHL (Unlu et al., 2014). Results of the present study indicated that with the exception of a single high result shown in industry one and the one other result in excess of the 50% additive OEL in industry two, all of the solvent levels found were low and in compliance with recommended additive exposure limits for mixed VOC's. Furthermore, solvents that were present in the industries included toluene, dichloromethane, xylene, trimethyl benzenes, n-hexane, acetone, aliphatic hydrocarbons (as white spirits) and benzene. Toluene was the highest solvent present across all three industries, followed by white spirits which was the second highest. Other high solvents that were present include xylene and acetone. Research reveals that of all the compounds of solvent mixtures, the influence of xylene and toluene on hearing seems to be the most important, because the ototoxicity of these particular chemicals were clearly demonstrated in the experiments on animals in various studies (Unlu et al., 2014). According to Morata (2003) in Unlu et al. (2014), accompanying exposure to noise and a solvent mixture in which toluene was the major component significantly affected hearing thresholds among refinery workers.

Research has revealed that the main cause of hearing loss in workers within industries is NIHL from noise exposure above 85dB (Mohammadi, Labbafinejad, & Attarchi, 2010). However, hearing loss can be made worse by exposure to both solvents and noise, even when noise is within the limits of 85dB (Mohammadi, Labbafinejad, & Attarchi, 2010). In this study, results revealed that industry one was exposed to a noise level in excess of 85 dB by 3dB, and industry two and three were exposed to levels within the permissible limits (≥ 85 dB). Workers presented with high frequency hearing loss in the present study, thus further reiterating that hearing loss can occur over a period of time even when solvent and noise levels are low and within the limits. Loukazadeh et al. (2014) have reported

that most studies have shown a synergistic effect on auditory function. Furthermore, solvents change the structure of the outer hair cells and cause them to become more sensitive to the effect of noise; therefore, simultaneous exposure to solvents and noise has a more potent effect on the cochlea. This was revealed in the present study due to the results of the DPOAE testing. The most common finding in SIHL in the inner ear is the degeneration of the sensory hair cells in the cochlea. In animal studies, both noise and solvent exposure have been shown to cause a loss of hair cells (Fuente, McPherson & Hickson, 2013). Research indicates that the cochlear damage induced by solvents starts from the third row of outer hair cells (OHC) and then progresses to the second and first row of OHC. Research further stated that the mid-frequency region of the cochlea of rats is particularly affected by solvents (Fuente, McPherson & Hickson, 2013). Due to this contradicting data, further research is needed to determine OHC dysfunction in workers exposed to solvents.

Results for DPOAEs revealed that all workers had reduced amplitudes across all three phases, with the exception of one pass result at one phase for one worker. It is interesting to note that the low frequencies were also affected amongst most of the workers. Sulkowski et al. (2002) found lower amplitudes for DPOAEs among solvent-exposed subjects in comparison to control subjects. Johnson (2007) in Fuente, McPherson and Hickson (2013) found significant differences between solvent-exposed and control subjects for the input/output function of the DPOAE only at lower intensities. Thus, further research is needed to determine OHC dysfunction in human subjects exposed to solvents. The other important issue is the possible added value of OAE measurements to be included within audiological test batteries, which are suggested to be more sensitive and predictive of cochlear dysfunction induced by solvents (Fuente, McPherson & Hickson, 2013).

Exposure to noise and solvents individually may have been below permissible levels, but it is plausible to assume that their combination can affect hearing (Loukzadeh, et al., 2014). This combined effect is of major concern to audiologists as they need to be more aware and implement HCP's for workers even when ototoxic substances are within the norm. The exposure to a mixture of solvents, as is the case in the present study, is more damaging on hearing than exposure to a single solvent (Metwally, Aziz, Mahdy-Abdallah, Abd ElGelil, & El-Tahlawy, 2012). Results obtained from the present study and previous studies demonstrate the importance of reducing noise exposure in environments with solvents to prevent "solvent-enhanced potentiation of NIHL" (Metwally et al., 2012, p. 906). This can be achieved by removing sources of noise or encouraging workers to wear HPD's. The current threshold limit values for solvents, despite being within the ACGHI (2006) recommended levels, clearly do not protect workers from hearing loss as proven in the current study due to workers experiencing hearing loss in the high frequencies. Therefore, effective intervention is needed to improve the safety of workers experiencing ototoxic effects of solvents combined with

noise. Conclusions from this study can help policy makers to re-evaluate the threshold limit values for workers exposed to noise combined with any solvent.

This study included the pure tone audiometric test to assess workers hearing status. Pure-tone audiometry testing can be extended to include the frequencies of 10KHz, 12KHz, 14KHz and 16 KHz, which is known as high-frequency audiometry. This assessment is an early indicator of hearing deficits to monitor ototoxicity (Ikharu, et al., 2000). In this study, pure tone threshold results revealed that all workers experienced normal hearing (equal or better than 25 dB) in the low-mid frequencies across all three phases. All the workers experienced hearing loss in the high frequencies, particularly at 12KHz across all the phases. Two of the workers did not experience hearing loss at 12KHz in the first and second phase of testing, however, developed hearing loss in phase three of testing after six months. This could be indicative of progression of hearing loss over time, therefore, motivating for periodic auditory monitoring.

Similar to the results in the present study, two different studies by Lobato, et al. (2014) and Fuente, McPherson, and Hickson (2013) revealed that workers presented with normal hearing across the frequency range even in the presence of noise and solvents. However, the workers exposed to solvents and noise had a poorer mean of thresholds than the control group. It was assumed that because the workers are not only exposed to the solvents, but also to noise, abnormal audiograms were found in the majority of the exposed workers. In the present study, such changes predominated in the higher frequencies of the pure tone audiograms, particularly at 12 KHz. This finding is commensurate with findings by Sulkowski, et al. (2002) which showed mainly a high frequency (above 1 kHz) hearing loss, identified in 42% of those exposed to solvents (Sulkowski, et al., 2002).

In more recent studies, it was reported that the upper limit of hearing has been used for early detection of ototoxic factors, such as noise and styrene, which is a good improvement for audiologists as this assessment can be moved towards being included in HCP's (Ikharu, et al., 2000). Tochetto, Quevedo and Siqueira (2013) further put forward that a wider range of frequencies are affected in exposures to solvents, when compared to the frequency range affected by noise, therefore high-frequency audiometry should be presented in investigations of SIHL in the long term (Tochetto, Quevedo, & Siqueira, 2013). Thus, this emphasizes the importance of conducting a more extensive hearing evaluation on these workers due to the risk of hearing loss to be greater when there is a combination of agents.

Another critical issue is that the conventional pure tone audiometry cannot detect hearing loss that occurs in the range of high frequencies. Changes in hearing thresholds for high frequencies found in this study reinforce what has been suggested by other researchers (Ikharu, et al., 2000), highlighting

the importance of the presence of high-frequency audiometry in the battery of tests performed in evaluating SIHL (Tochetto, Quevedo, & Siqueira, 2013). In a study similar to the present one, Rabinowitz et al. (2006) concluded that solvent exposure was significantly linked with high-frequency hearing loss. The workers in the study were also exposed to low levels of solvent exposure with the time of observation being quite short, and workers still developed additional hearing loss at high-frequencies.

The present study revealed that there was auditory dysfunction even when solvents were within OEL's, therefore there still is a reason for concern and workers should take the relevant precautions. The research published proves this and proposes that such solvents may be harmful to hearing even at concentrations within the limits advised by international agencies (Metwally et al., 2012). Consistent with previous studies, the findings are also pointing out that currently suggested solvent exposure limit values are insufficient to protect workers at risk from auditory damage (Unlu et al., 2014). According to legislation, noise in the workplace has exposure standard levels that need to be abided by to be safe for human hearing (Johnson & Morata, 2010). Solvents in the workplace also need exposure standards to protect workers from SIHL. Research institutions such as NIOSH (1994) and ACGIH (2006) recommend that workers exposed to solvents undergo audiometric testing. In Brazil, labour legislation does not recommend periodic audiometric examinations in workers exposed to solvents except for those exposed to noise levels above 85 dBA for 8 hours per day (Lobato et al., 2014). However, due to minimal research on the exposure-response relationship between solvents and hearing loss, there has been no standards stipulated for PELs specific to protect human hearing (Johnson & Morata, 2010). There are only recommended PELs for airborne exposure to solvents with none being available in SA. In developing countries like SA, there are no regulations or laws regarding SIHL, and industries allow workers to work under adverse conditions without being informed about the consequences. Audiologist's need to play an active role in the protection of workers hearing within industries. It is envisaged that research studies such as the present, can add evidence to the limited existing body of knowledge so that such evidence can be used to formulate guidelines and regulations. Air monitoring of substances and risk management assessments should be conducted by the industry in order to protect workers from SIHL (SWA, 2012).

The present study revealed that workers had reported symptoms associated with solvent exposure. These reports are of importance as other research has shown that solvents could cause dizziness, headaches, nausea and balance (Hodgkinson & Prasher, 2006). Furthermore, solvents could also cause damage to the internal organs, such as the kidneys and liver, and are known to cause diseases like cancer. Audiologists need to include questions regarding the symptoms experienced from solvents into case history questionnaires when assessing workers as the answers will lead to better management of the workers. Furthermore, researchers need to be aware of all the side effects involved

in order to appropriately manage and refer workers to the relevant professionals. Other studies have not investigated symptoms associated with SIHL in detail, and focused mainly on the ototoxic effects of solvents on the central auditory and vestibular systems (Hodgkinson & Prasher, 2006). This leaves room for researchers to further investigate the health related symptoms associated with SIHL.

In summary, the present study revealed that workers exposed to both solvents and noise which were within permissible levels, presented with high frequency hearing loss. Pure tone thresholds were compared to DPOAEs and the results revealed that there were no differences between pure tone audiometry and DPOAEs in the monitoring of auditory function in the high frequency, mid frequency and low frequency range in a group of workers. This implies that there was no presence of subclinical hearing loss. No significant results were obtained and this could be due to the small sample size of the study. Research reveals that only a few studies have used DPOAEs as an assessment tool for SIHL (Prasher et al., 2005; Hoffmann, Ihrig, Hoth, & Triebig, 2005; Fuente, McPherson, & Hickson, 2013). Research has further indicated that the OHC's are the most vulnerable and most easily affected by solvents, and OAEs can be used to detect these impaired OHC's as they are more sensitive in detecting early symptoms of SIHL as opposed to pure tone audiometry (Prasher et al., 2005; Hoffmann et al., 2005; Fuente, McPherson, & Hickson, 2013). Sulkowski et al. (2002) found lower amplitudes for OAEs among participants exposed to solvents in comparison to control participants. In another study, Johnson et al. (2006) in Fuente, McPherson, and Hickson (2013) did not find a significant association between solvent exposure and OAEs. Therefore, with the conflicting literature regarding the use of OAE testing for SIHL, further research needs to be conducted to clarify the significance of OAE testing within a test battery (Fuente, McPherson, & Hickson, 2013).

The role of the audiologist regarding SIHL is not clearly outlined in the studies mentioned. SIHL is a fairly new concern in the field of audiology and presents new challenges for audiologists. Many audiologists are not aware of SIHL, as most research results are published in occupational health journals, which are not typically reviewed by audiologists (Fuente & McPherson, 2006). Audiologists need to keep updated with new knowledge about hazards to hearing in order to be able to implement programs for such target groups. They also need to conduct further research within the SIHL field to expand the literature available, especially with regard to the mechanism and pathophysiology of ototoxic agents, as there is limited research in this area. Results from research conducted can help policy makers establish threshold limit values. Audiologists also have a responsibility to provide information and awareness campaigns to management and stakeholders in order to promote the conservation of hearing among workers. This is particularly important, as certain industries expose their workers to varying levels of solvents depending on the task at hand, with audiologists needing to be aware of the risks to be able to discuss them with management. Audiologists are capable of conducting HCP for workers exposed to solvents. Johnson and Morata (2010) recommend that

adjustments need to be made to the HCP in combined chemical and noise industries. These adjustments include: taking chemical exposures into account when monitoring air exposures, assessing workers who are exposed to chemicals more regularly, as well as using different methods for controlling workers exposures to chemicals (Johnson & Morata, 2010). Researchers also suggested that the HCP needs to include short-interval audiometric evaluations, high frequency audiometry, and efficient hearing protection devices (HPD) (Mohammadi, Labbafinejad, & Attarchi, 2010).

Future studies need to focus on a longitudinal study design as this will increase the sample size and thus improve generalization. One of the main limitations noted in the studies was small sample sizes, thus minimal conclusions could be drawn from the studies (Prasher et al., 2005; Schäper, Seeber, & Van Thriel, 2008; Kim et al., 2005; Chang, Chen, Lien, & Sung, 2006). In addition, it is worthwhile for research studies to vary the study design from a cross sectional to a longitudinal design as the studies mentioned used a cross-sectional design and the main limitation of this design is that it cannot establish causal relations (Berg & Latin, 2004). Using a longitudinal design will allow the researcher to assess ototoxic effects effectively, as literature reveals that ototoxic effects occurs over a period of time (Gelfand, 2009). Future research needs to focus on stricter inclusion and exclusion criteria. Researchers did not impose the age limit on their participants in order to control for age effects on hearing. The results could be confounded due to some workers being above the age of 60 years when typically presbycusis sets in (Ikuharu, et al., 2000); therefore imposing age as a strict inclusion criterion is necessary. Furthermore, workers within industries may present with variables that may influence the cause and effect relationship (such as factors that affect their hearing, e.g. smoking) regarding noise and solvent exposure on their auditory system, which some studies did not consider, further highlighting the need for stringent inclusion and exclusion participant criteria (Ikuharu, et al., 2000). Cumulative dose of exposure is the total dose from conducting repeated air measurements over a period of time (Mohammadi, Labbafinejad, & Attarchi, 2010). The cumulative dose of exposure is relevant; as it could determine current threshold limits for solvent exposure (Mohammadi, Labbafinejad, & Attarchi, 2010). There was a lack of information regarding previous solvent exposure levels of workers and this measure was not calculated for all studies. Further research studies conducted should attempt to obtain matching sample size numbers in order for appropriate conclusions to be made. Some studies had unmatched numbers across groups, thus only limited conclusions could be drawn from the studies (Prasher et al., 2005). It is recommended that personal dosimetry measurements be conducted for both noise and air measurements as this will allow for more specific analysis of results per worker. There was a lack of individual samplings (dosimeter and air measurements) of toluene from participants during solvent exposure measurements (Schäper, Seeber, & Van Thriel, 2008). Furthermore, literature states that once solvents are absorbed into the body via inhalation, the body's metabolic system transforms the solvents into components that are

present in blood and then excreted in urine. This demonstrates the need to be able to adequately monitor workers exposed to solvents by monitoring their metabolites (blood and urine) for traces that have been in their system as well as the solvent concentrations in the air (Prasher et al., 2005). The limitation across all of the reviews mentioned was that there was no testing of urine and blood of the workers, therefore, future research projects should include these tests as it could add validity to research findings.

4.4. Conclusion

This chapter revealed the results and discussion for aim one and aim two. The findings of aim one concluded that there are significantly higher odds of acquiring hearing loss when workers are exposed to a combination of solvents and noise as opposed to solvents only. Globally, there is limited research available on noise and solvent interactions and their effects on hearing. Furthermore, there are only a few comparative studies with varied conclusions, requiring further investigation into the effects of the combined exposure on hearing. The findings of aim two suggest that participants were exposed to noise and solvents within the suggested limits, however, pure tone threshold results revealed normal hearing for the low and mid frequencies but hearing loss at the high frequencies, particularly at 12KHz. Results for DPOAEs revealed that all workers had reduced amplitudes across all three phases with the exception of one pass result at one phase for one worker. Furthermore, when pure tone thresholds and OAEs were compared, the statistics indicated that there were no significant difference between pure tone audiometry and DPOAEs in detecting normal and abnormal responses for both ears across the low, mid and high frequency ranges of 500Hz, 1000Hz and 12000Hz, and the geometric means of 750Hz, 1000Hz and 8000Hz. Unfortunately, the sample size of the study was too small to yield significant results. However, this does imply that there was no presence of subclinical hearing loss amongst participants. Time series data revealed no significant results for changes over time regarding pure tones and DPOAEs and workers hearing function. The sample of 12 workers (24 ears) was too small to reveal any significant results. Lastly, participants reported on symptoms experienced from exposure to solvents. In particular, the participants reported on headaches, dizziness, blurry eyes and breathing problems.

CHAPTER 5

CONCLUSION, IMPLICATIONS FOR FUTURE RESEARCH AND LIMITATIONS OF THE STUDY

5.1 Introduction

This is the final and concluding chapter, which provides a summary of the findings, as well as clinical and research implications. Limitations and recommendations for future studies are provided.

5.2 Concluding summary

5.2.1. *Aim one*

The findings of the systematic review and meta-analysis concluded that there are significantly higher odds of acquiring hearing loss when workers are exposed to a combination of solvents and noise as opposed to solvents only. Globally, there is limited research available on noise and solvent interactions and their effects on hearing. Furthermore, there are only a few comparative studies with varied conclusions, requiring further investigation into the effects of the combined exposure on hearing. Most industries do not control the levels of solvents that they use and do not take into consideration regulations concerning the use of ventilation systems and the provision of masks, gloves or other personal protective equipment which could harm workers, therefore making workers more susceptible to detrimental effects on the auditory system as a result of combined solvent exposure.

The challenge for the audiologist is that in an occupational environment, since the workers are usually exposed to mixtures of substances, it is not easy to evaluate the effects associated with exposure to a specific chemical. In addition, most threshold limit values are established for a single solvent; however, industries are often composed of several solvents simultaneously. Thus, developed occupational threshold limits are currently based on isolated workplace hazards that are not adequate for protecting workers who may be exposed to multiple solvents in industries coincidentally and sequentially (Mirzaei & Ansari-Moghaddam, 2012). Therefore, recommendations emerging from the studies regarding SIHL for audiologists include:

- Prioritizing personal solvent monitoring (Gelfand, 2009)
- Evaluating personal protective equipment use (Gelfand, 2009)
- Appropriate recording: Health results of workers should be recorded and checked regularly in order to detect early changes at individual and collective levels (Mirzaei & Ansari-Moghaddam, 2012).

- Risk management measures aimed at reducing exposure to ototoxic substances should be encouraged (Nies, 2012).
- Ototoxicity monitoring that should be made a part of occupational health-screening activities (Nies, 2012).
- Suitable scientific investigations into ototoxic properties should be encouraged such as longitudinal epidemiological studies (Nies, 2012).

5.2.2. Aim two

Within the constraints of the small sample sizes, only limited conclusions could be drawn from this study. However, despite these limitations, the study still established interesting and valid observations. The findings of aim two suggest that participants were exposed to noise and solvents within the suggested limits. Pure tone threshold results revealed normal hearing for the low and mid frequencies. All workers across the three phases experienced hearing loss at the high frequencies, particularly at 12KHz. Results for the OAEs revealed varied outcomes with lower amplitudes in the low and high frequencies particularly. Furthermore, when pure tone thresholds and OAEs were compared, the statistics indicated that there was no significant difference between pure tone audiometry and DPOAEs in detecting normal and abnormal responses for both ears across the low, mid and high frequency ranges of 500Hz, 1000Hz and 12000Hz, and the geometric means of 750Hz, 1000Hz and 8000Hz. Unfortunately, the sample size of the study was too small to yield significant results. Time series data revealed no significant results for changes over time regarding pure tones and DPOAEs and workers hearing function. Other research studies have revealed that OAE testing is important to include in the test battery for SIHL as it is able to detect even small changes in the OHC's. A limitation of the study was the small sample. Due to limited access to industries, a relatively small number of workers participated. Due to the small sample size, generalization among workers was restricted. Furthermore, the study involved workers from industries who work full time as well as having high demanding jobs; therefore the dropout rate was high. Lastly, participants reported on symptoms experienced from exposure to solvents. In particular, the participants reported on headaches, dizziness, blurry eyes and breathing problems. Researchers need to consider including a health questionnaire in the assessment of workers with SIHL to assist the worker holistically.

From the results of the study, audiologists need to advocate for solvent limits to be lowered as participants experienced hearing loss even when solvents were within the limits. Audiologists also need to include workers into HCP's when they are exposed to both noise and solvents. Unfortunately, the sample size of the current study was too small. This implies that future researchers need to conduct studies with larger sample sizes in order for more significant results to be obtained. To further combat the issue of small sample sizes, researchers need to formulate methods to encourage industry managers to allow access into industries in order for research to be conducted to benefit the workers

without implicating industries. The current research is of high importance within SA due to the number of industries present in the country and the results obtained from the study can assist audiologists to make changes to the current HCP's to benefit workers as well as implement an accurate and comprehensive programme. This program could include short-interval audiometric examinations; use of more effective hearing protectors and the use of solvent protectors as these are essential for industries whose workers are exposed to a combination of solvents and noise. Damage to the auditory system was mostly recognized at high frequency levels, therefore workers should be followed with high-frequency audiometry as well.

5.3. Research implications:

Research implications of this study are:

- i. To conduct further studies in South Africa to gain a better understanding of the association between noise and solvent exposure on the auditory system locally.
- ii. To conduct a similar study on a larger population to obtain additional accurate results.
- iii. To use the findings of this research project as a basis to formulate a program on informing workers regarding the effects of solvents on hearing.
- iv. To conduct a similar study with additional dosimeter readings as well as additional air measurements to determine personal levels to formulate further inferences.
- v. Researchers to design a method to be able to obtain a representative sample as well as to attain assurances from the industries prior to commencement of the study. In order for this to happen, researchers need to build a strong foundation with managers by dispelling their fears regarding the researcher not imposing legislation on the industry.
- vi. To develop a comprehensive hearing conservation program on educating and training workers regarding the prevention of solvent induced hearing loss.

In addition to the above, the present study provides various clinical implications.

5.4. Clinical implications:

Clinical Implications of this study are that:

- i. Workers from the current study reported symptoms of dizziness, headaches and blurry eyes. The literature further suggested that workers exposed to solvents could present with vestibular

disorders, therefore future research can focus on the testing of the vestibular system of workers exposed to solvents.

- ii. The literature suggested that workers exposed to solvents could present with central auditory processing disorders, therefore future research that includes the testing of the central auditory processing system of workers exposed to solvents are imperative.
- iii. The results from the current study as well as literature indicated that workers exposed to solvents could present with high frequency hearing loss, therefore future research can focus on the testing of the higher frequencies of workers exposed to solvents.

5.5. Limitations:

The following are the limitations of the study:

- i. A total of 43 workers were recruited for the study, however, only 12 participants were used in the study. Due to limited access to industries, a relatively small number of workers participated. Due to the small sample size, generalization among workers was restricted.
- ii. Due to time constraints, participants had to be easily and quickly accessible in a limited amount of time. The study was limited to one geographical area across three institutions.
- iii. The representativeness of the sample was limited by the fact that majority of the sample comprised of workers who were within the 18-50 year range.
- iv. The study entailed areas out of the researchers' scope of practice, thus minimal training was obtained and the researcher had to rely on assistance from specialists in the field.
- v. Due to this study being one of the first publications in South Africa, the researcher had to rely on international information and standards to conduct the study.
- vi. The study involved workers from industries who work full time as well as having high demanding jobs, therefore the dropout rate was high.
- vii. The researcher focused on paint and shoe manufacturing industries specifically as well as one area only; therefore minimal industries were obtainable which led to minimal workers participating in the study.

5.6. Conclusion

The present study reveals that there are significantly higher odds of acquiring hearing loss when workers are exposed to a combination of solvents and noise as opposed to solvents only. Globally, there is limited research available on noise and solvent interactions and their effects on hearing. Therefore, in conclusion, the present study supports that exposure to solvents may increase the risk of hearing loss due to noise exposure. The researcher recommends that workers in industries dealing with solvents are susceptible to SIHL, and industries should prioritize noise and solvent reduction to prevent hearing loss.

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7. LIST OF APPENDICES

APPENDIX A

Submission to journal

Dear Dr. Nakhooda,

Noise and Health has received your manuscript entitled "The effects of combined exposure of solvents and noise on auditory function-a systematic review and meta-analysis" for consideration for publication. The reference number for this manuscript is "NAH_114_15". Kindly quote this in correspondence related to this manuscript.

The manuscript is being reviewed for possible publication with the understanding that it is being submitted to one journal at a time and have not been published, simultaneously submitted, or already accepted for publication elsewhere either as a whole or in part. Online submission of this article implies that the corresponding author has the written consent from all the contributors to act as corresponding author.

You are requested to send the signed copyright/contributor form within two weeks. The form can be uploaded as an scanned image from your area. The decision about the manuscript will be conveyed only on receipt of the form. High resolution images are required at the time of acceptance, you should be notified separately for the same, if images uploaded by you are not of printable quality.

The Editors will review the submitted manuscript initially. If found suitable, it will follow a double-blinded peer review. We aim to finish this review process within a short time frame, at the end of which a decision on the suitability or otherwise of the manuscript will be conveyed to you via this system. During this process you are free to check the progress of the manuscript through various phases from our online manuscript processing site <http://www.journalonweb.com/nah>.

We thank you for submitting your valuable work to the Noise and Health.

Yours sincerely,
The Editorial Team
Noise and Health

APPENDIX B

CHARACTERISTICS OF STUDIES

CHARACTERISTICS OF INCLUDED STUDIES

ARTICLE: Evaluation of combined effect of organic solvents and noise by the upper limit of hearing	
AUTHOR: Ikuharu, Nobuyuki, Hiroichi, & Kazuhisa, 2000	
MEIHOIDS	Upper limit of hearing was tested (500Hz to 50KHz). Air conduction testing done.
PARTICIPANTS	54 male workers between 20-68 years. Divided into 3 groups, 23 combined group, 19 noise group, 12 control group.
RESULTS	Noise levels and solvent levels were within occupational exposure limits. No significant correlation was found between upper limit of hearing and pure tones and organic solvent concentrations in the working environment. Reduction of upper limit of hearing was largest in combined group, thus there could be a probable combined effect on hearing even when levels are within limits.
OUTCOMES	A probable combined effect of solvents and noise on hearing even when levels were relatively low.

ARTICLE: Combined effects of noise and mixed solvents exposure on the hearing function among workers in the aviation industry	
AUTHOR: Kim, Park, HA, Jung, Paik, & Yang, 2005	
MEIHOIDS	Solvents included methyl ethyl ketone, toluene, xylene and methyl isobutyl ketone. PURE-TONE AUDIOMETRY was used. 14 hour rest period before testing.
PARTICIPANTS	328 male workers from avionics jobs. Exposure to noise (146), solvents (18), noise and solvents (13), none (151).
RESULTS	Prevalence of hearing loss in noise and solvent group was higher than other groups (54.9%).
OUTCOMES	Chronic exposure to mixed solvents had a toxic effect on the auditory system.

ARTICLE: Effect of exposure to a mixture of solvents and noise on hearing and balance in aircraft maintenance workers	
AUTHOR: Prasher, Al-Hajjal, Aylott, & Aksentijevic, 2005	
MEIHOIDS	PT, OAEs, ABR, VNG and Posturography were done.
PARTICIPANTS	4 groups were tested- noise only, solvents only, noise and solvents, none.
RESULTS	There was a significant effect on PURE-TONE AUDIOMETRY thresholds for noise and for noise and solvent groups. OAEs declined with frequency and showed lower DP amplitude with noise compared to noise and solvent group. 32% of workers had abnormalities of ABR who were exposed to noise and solvents. 32% of workers in solvents and noise group had abnormal posturography results. Workers had abnormal results for VNG results in noise and solvent group.
OUTCOMES	The effects of a mixture of solvents on the auditory system appears to occur both at the end organ level as well as in the nervous pathway.

ARTICLE: Hearing loss in workers exposed to toluene and noise	
AUTHOR: Chang, Chen, Lien, & Sung, 2006	
MEIHOIDS	Cross sectional design- 1 study group and 2 reference groups. Used PT testing.
PARTICIPANTS	174 workers at an adhesive materials manufacturing plant. 58 workers exposed to toluene and noise- 58 workers exposed to noise- 58 admin clerks.
RESULTS	Higher prevalence of hearing loss in toluene and noise group. Hearing impairment higher at 1KHz than 2KHz. Mean hearing threshold lowest at 6KHz and least effect observed at 2KHz.
OUTCOMES	Toluene exacerbates hearing loss in a noisy environment, with the main impact at lower frequencies

ARTICLE: The effects of toluene plus noise on hearing thresholds: an evaluation based on repeated	
AUTHOR: Schaper, Seeber, & Van Thriel, 2008	
MEIHOIDS	4 repeated measures over 5 years were done. PURE-TONE AUDIOMETRY was done.
PARTICIPANTS	333 male workers
RESULTS	The threshold for developing hearing loss as a result of occupational exposure to toluene plus noise was above the current limit of 50ppm.
OUTCOMES	Due to missing toluene effects, the conclusion is that the threshold for developing hearing loss as a result of occupational exposure to toluene plus noise might be above the current limit of 50ppm.

ARTICLE: Comparative study of audiometric tests on metallurgical workers exposed to noise only as well as noise associated to the handling of chemical products	
AUTHOR: Botelho, Paz, Gonçalves, & Frota, 2009	
METHODS	14 hour rest period before testing. AC, BC, SRT, SRS was done.
PARTICIPANTS	155 workers exposed to noise only 81 (group 1) and also noise and chemicals 71 (group 2). Age 18-50 years. Working for a period of 3-20 years.
RESULTS	Greater hearing loss in group 2 (18.3%) than group 1 (6%). Chemicals found were styrene, resins and cobalt.
OUTCOMES	Group 2 had a proportionally higher hearing loss than group 1.

ARTICLE: Combined effects of ototoxic solvents and noise on hearing in automobile plant workers in Iran	
AUTHOR: Mohammadi, Labbafinejad, & Attarchi, 2010	
METHODS	Cross sectional design. Automobile plant. PURE-TONE AUDIOMETRY was done.
PARTICIPANTS	All workers who worked for more than 6 months. All male. 164 in old paint shop (noise and mixed solvents at high concentration levels). 104 new (noise and mixed solvents at low concentration levels). 173 assembly shop (noise only).
RESULTS	Solvents found were xylene, toluene, benzene, tetrachloroethylene and acetone. High frequency hearing loss was more common in workers exposed to noise and mixed solvents.
OUTCOMES	Combined exposure to mixed solvents and noise can exacerbate hearing loss.

ARTICLE: Audiometric findings in petrochemical workers exposed to noise and chemical agents	
AUTHOR: Barba, Jurkiewicz, Zeigelboim, de Oliveira, & Belle, 2005	
METHODS	The records of environmental noise and solvents measurements and the results of annual audiometry performed by the company were examined.
PARTICIPANTS	2 groups: group 1 (solvents and noise) and group 2 (noise).
RESULTS	Despite the low exposures to solvents and a moderate exposure to noise, 45.3% of workers had hearing losses and 29.6% had threshold shifts.
OUTCOMES	This study suggests the necessity for reviewing the preventive measurements adopted by the company studied for eliminating the occurrence of hearing losses and standard threshold shift.

ARTICLE: Auditory Effects of Exposure to Noise and Solvents: A Comparative Study	
AUTHOR: Lobato, De Lacerda, Gonçalves, & Coifman, 2014	
METHODS	A transversal retrospective cohort study was performed
PARTICIPANTS	198 workers 4 groups: noise group, exposed only to noise; the noise and solvents group, exposed to noise and solvents; the noise control group and noise and solvents control group, no exposure.
RESULTS	The noise group and noise and solvent group had worse thresholds than their respective control groups. Females were less susceptible to noise than males; however, when simultaneously exposed to solvents, hearing was affected in a similar way. The 40- to 49-year-old age group was significantly worse in the auditory thresholds.
OUTCOMES	The results observed in this study indicate that simultaneous exposure to noise and solvents can damage the peripheral auditory system.

ARTICLE: Evaluation of the effects of exposure to organic solvents and hazardous noise among US Air Force Reserve personnel	
AUTHOR: Hughes & Hunting, 2013	
METHODS	Data were collected retrospectively from existing audiometric examinations, industrial hygiene documentation
PARTICIPANTS	4 exposure profiles: Noise with solvents, noise alone, solvents alone and neither noise nor solvents. 503 workers from two Air Force Reserve sites. 41 subjects did not meet the study inclusion criteria.
RESULTS	Followed for an average of 3.2 years, 9.2% of the study subjects had hearing loss in at least one ear. Increasing age and each year of follow-up time were significantly associated with hearing loss. Low and moderate solvent exposures were not associated with hearing loss.
OUTCOMES	Workers who are exposed to increasing levels of noise gradually lose hearing sensitivity over time.

ARTICLE: Health hazards among a sample of workers exposed to a combination of noise and organic solvents in a fermentation factory in Egypt	
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AUTHOR: Rizk & Sharaf, 2010	
METHODS	All studied sample were subjected to complete medical examination and audiometric examination using pure tone Audiometer.
PARTICIPANTS	110 workers in a fermentation plant divided into two groups. Group A (50 workers,) exposed to noise only, group B (60 workers) exposed to noise and mixture of organic solvents, Control group (group C; 30 workers) were neither exposed to noise nor organic solvents.
RESULTS	Noise level was comparable in groups A&B but significantly higher than in control work places. Thirty six percent of exposed workers suffered from hearing loss versus 3.3 percent in the control group. Hearing loss was significantly higher among group B (24%) than group A (18%). Results showed that both exposed groups had higher hearing loss than normal control.
OUTCOMES	Workers exposed to both noise and organic solvents suffered from the highest proportion of hearing loss compared to those exposed to noise alone.

ARTICLE: Hearing Loss in Workers Exposed to Carbon Disulfide and Noise	
AUTHOR: Chang, Shih, Chou, Chen, Chang, & Sung, 2003	
METHODS	-
PARTICIPANTS	131 men with exposure to noise and CS ₂ in a viscose rayon plant. 105 men in the adhesive tape and electronic industries who were exposed to noise only 110 men employed in the administrative office of the rayon plant who were exposed to low noise and no CS ₂ .
RESULTS	Results showed a prevalence of hearing loss of > 25 dB hearing loss in rayon workers (67.9%) was much higher than that in administrative workers (23.6%) and in the adhesive tape and electronic industrial workers (32.4%). Hearing loss occurred mainly for speech frequencies of 0.5, 1, and 2 kHz.
OUTCOMES	The study suggests that CS ₂ exposure enhances human hearing loss in a noisy environment and mainly affects hearing in lower frequencies.

ARTICLE: Effect of combined occupational exposure to noise and organic solvents on hearing	
AUTHOR: Metwally, Aziz, Mahdy-Abdallah, Said AbdElGelil, & El-Tahlawy, 2012	
METHODS	Questionnaires were given to workers; Otoscopic examinations were conducted as well as pure tone audiometry.
PARTICIPANTS	3 groups 70 workers exposed to noise only, the second group consisted of 93 workers exposed to organic solvents and noise, and the control group included 59 individuals exposed to neither noise nor organic solvents.
RESULTS	No statistically significant difference between the two exposed groups as regards the duration of exposure. There was a highly statistically significant difference between the two exposed groups as regards the different types of hearing. The difference between the two groups was statistically significant regarding this type of hearing impairment. There was a positive significant correlation between hearing impairment and duration of exposure in the two exposed groups.
OUTCOMES	It is recommended that in the case of combined exposure, noise and solvent levels should be lowered than the permissible limits recommended for either alone.

CHARACTERISTICS OF EXCLUDED STUDIES

ARTICLE: Auditory neuropathy in a patient exposed to xylene: case report	
AUTHOR: Draper & Bamiou, 2009	
METHODS	-
PARTICIPANTS	1 adult
RESULTS	The patient presented with a gradual deterioration in his ability to hear in difficult acoustic environments and also to hear complex sounds such as music, over a 40-year period. His symptoms began following exposure to the solvent xylene, and in the absence of any other risk factor. Audiological investigations revealed normal OAEs with absent ABR and absent acoustic reflexes in both ears, consistent with a diagnosis of bilateral auditory neuropathy. Central test results were also abnormal, indicating possible involvement of the central auditory pathway.
OUTCOMES	This is the first report of retrocochlear hearing loss following xylene exposure. The test results may provide some insight into the effect of xylene as an isolated agent on the human auditory pathway.

ARTICLE: Audiological findings in individuals exposed to organic solvents: case studies	
AUTHOR: Gopal, 2008	
METHODS	A battery of audiological tests was administered to all subjects: PURE-TONE AUDIOMETRY, speech, and impedance audiometry, OAEs, ABR, MLR, as well as the SCAN-A and R-SPIN tests with low predictability sentence lists.
PARTICIPANTS	7 adults- exposed to toluene, xylene, styrene.

	Exposed at least 3 years.
RESULTS	All individuals in this study exhibited findings consistent with retrocochlear and/or central abnormality. Two of the seven subjects in this study had normal pure tone thresholds at all frequencies bilaterally, yet showed abnormal retrocochlear/central results on one or more tests.
OUTCOMES	The auditory test battery approach used in this study appears to be valuable in evaluating the pathological conditions of the CANS in solvent-exposed individuals.

ARTICLE: Styrene Induced Alterations in Biomarkers of Exposure and Effects in the Cochlea: Mechanisms of Hearing Loss	
AUTHOR: Chen, Chi, Kostyniak, & Henderson, 2007	
MEIHDOS	In this study, rats were exposed to styrene at different doses once a day for varying periods.
PARTICIPANTS	Long Evans pigmented rats (male, 330 ± 32 g) were used
RESULTS	Styrene levels in the cochlear tissues, styrene induced permanent hearing loss, cochlear disruptions, and cell death pathways were determined. After 3 weeks of exposure (5 days per week), a dose-dependent permanent hearing loss and a hair cell loss, especially in the mid frequency region, were observed. Deiters cells appeared to be the most vulnerable target of styrene.
OUTCOMES	Apoptotic cell death appeared to be the main cell death pathway in the cochlea after styrene exposure. In the styrene-induced apoptotic OHCs, histochemical staining detected activated caspases-9 and 8, indicating that both mitochondrial dependent pathway and death receptor-dependent pathway were involved in the styrene-induced cell death.

ARTICLE: Potentiation of noise induced threshold shifts and hair cell loss by carbon monoxide	
AUTHOR: Fechter, Young, & Carlisle, 1988	
MEIHDOS	Rats received acute exposure to carbon monoxide, noise, or both agents concurrently. Thresholds were evaluated 2-4 and 6-8 weeks later.
PARTICIPANTS	Subjects were 16 male Long-Evans hooded rats, weighing between 300 and 350 g at the start of testing.
RESULTS	The data showed that carbon monoxide alone does not affect either auditory thresholds or compromise hair cells at the light microscopic level. The noise exposure alone produced variable, but quite limited permanent threshold shifts which were related to the power spectrum of the broad band noise that was employed. Hair cell loss was restricted to the basal turn of the cochlea. Simultaneous exposure to carbon monoxide and noise induced large threshold shifts at all frequencies studied, but the effect was greatest at the highest test frequency; an effect not consistent with the noise power spectrum. Widespread hair cell loss persisted over fully half of the basilar membrane in the most severely affected rat. Outer hair cells appear to be particularly vulnerable. Carbon monoxide plus noise did not appear to preferentially disrupt a particular row of outer hair cells.
OUTCOMES	These data complement existing evidence that hyperoxia can mitigate against noise induced injury and reinforce the view that some types of noise induced damage may result from metabolic insufficiencies.

ARTICLE: Ototoxicity of Toluene in Rats	
AUTHOR: Sullivan, Rarey, & Conolly, 1989	
METHODS	BAER thresholds were recorded from four toluene-treated and four control rats prior to dosing (main experiment) and from all rats after dosing (both experiments).
PARTICIPANTS	In the preliminary experiment, 5 male Sprague-Dawley rats were used. In the main experiment, eight male Sprague-Dawley rats were used.
RESULTS	Loss of outer hair cells occurred in all toluene-treated rats in the middle and basal turns of the organ of Corti, with the greatest loss in the third row and progressively less in the second and first rows. This loss was more severe in toluene-treated rats that demonstrated elevated BAER thresholds in midfrequency regions, typically 2-8 kHz.
OUTCOMES	These experiments demonstrate that auditory changes are associated with cochlear hair cell loss in toluene-treated rats. These ototoxic effects of toluene contrast with those of other known ototoxicants, e.g., aminoglycoside antibiotics, in terms of the position of hair cell lesion in the organ of Corti and in the pattern of hair cell loss.

APPENDIX C

No.	YEAR	COUNTRY	ARTICLE	EXPOSURE	OBJECTIVE	MEIHOD	RESULTS	CONCLUSION	REFERENCE S
1	2000	Japan	Evaluation of combined effect of organic solvents and noise by the upper limit of hearing	Organic Solvents and Noise	To clarify the combined effect of organic solvents and noise on the upper limit of hearing in workers occupationally exposed to both organic solvents and noise at relatively low levels.	54 male workers between 20-68 years. Divided into 3 groups, 23 combine group, 19 noise group, 12 control group. Upper limit of hearing was tested (500Hz to 50KHz) and air conduction testing done.	Noise levels and solvent levels were within occupational exposure limits. No significant correlation was found between upper limit of hearing and pure tones and organic solvent concentrations in the working environment Reduction of upper limit of hearing was largest in combine group, thus there could be a probable combined effect on hearing even when levels are within limits.	A probable combined effect of solvents and noise on hearing even when levels were relatively low	Ikuharu, Nobuyuki, Hiroichi, & Kazuhisa, 2000
2	2005	Korea	Combined effects of noise and mixed solvents exposure on the hearing function among workers in the aviation industry	Noise and Mixed Solvents	To evaluate the effects of occupational lifetime exposure to noise and organic solvents on hearing loss in the aviation industry	328 male workers from avionics jobs. Solvents included methyl ethyl ketone, toluene, xylene and methyl isobutyl ketone. Exposure to Noise (146), solvents (18), noise and solvents (13), none (151). Pure-tone audiometry was used. 14 hour rest period before testing.	Prevalence of hearing loss in noise and solvent group was higher than other groups (54.9%).	Chronic exposure to mixed solvents had a toxic effect on the auditory system.	Kim, Park, HA, Jung, Paik, & Yang, 2005
3	2005	-	Effect of exposure to a mixture of solvents and noise on hearing and balance in aircraft maintenance workers	Solvents and Noise	To evaluate the effects of solvents and noise on hearing and balance in workers.	4 groups were tested- noise only, solvents only, noise and solvents, none. Pure Tone, OAEs, ABR, VNG and Posturography were done.	There was a significant effect on pure-tone audiometry thresholds for noise and for noise and solvent groups. OAEs declined with frequency and showed lower DP amplitude with noise compared to noise and solvent group. 32% of workers had abnormalities of ABR who were exposed to noise and solvents. 32% of workers in solvents and noise group had abnormal posturography results. Workers had abnormal results for VNG results in noise and solvent group.	The effects of a mixture of solvents on the auditory system appears to occur both at the end organ level as well as in the nervous pathway.	Prasher, Al-Hajjal, Aylott, & Aksentijevic, 2005
4	2006	Taiwan	Hearing loss in workers exposed to toluene and noise	Toluene and Noise	To evaluate long term effects of combined exposure to toluene and noise on audiometric thresholds	Cross sectional design- 1 study group and 2 reference groups. 174 workers at an adhesive materials manufacturing plant. 58 workers exposed to toluene and noise- 58 workers exposed to noise- 58 admin clerks. Used Pure Tone testing.	Higher prevalence of hearing loss in toluene and noise group. Hearing impairment higher at 1KHz than 2KHz. Mean hearing threshold lowest at 6KHz and least effect observed at 2KHz.	Toluene exacerbates hearing loss in a noisy environment, with the main impact at lower frequencies	Chang, Chen, Lien, & Sung, 2006
5	2008	Germany	The effects of toluene plus noise on hearing thresholds: an evaluation based	Toluene and Noise	The ototoxicity of occupational exposure to toluene and noise was investigated in a	4 repeated measures over 5 years were done, 333 male workers. Pure-tone audiometry was done.	The threshold for developing hearing loss as a result of occupational exposure to toluene plus noise was above the current limit of 50ppm.	Due to missing toluene effects, the conclusion is that the threshold for developing hearing loss as a result of	Schaper, Seeber, & Van Thriel, 2008

			on repeated measurements in the German printing industry		longitudinal study in rotogravure printing and existing findings in the literature was evaluated			occupational exposure to toluene plus noise might be above the current limit of 50ppm.	
6	2009	Rio de Janeiro	Comparative study of audiometric tests on metallurgical workers exposed to noise only as well as noise associated to the handling of chemical products	Noise and Chemicals	To perform a comparative study through audiometric tests in workers exposed to noise only and noise associated with chemical products	155 workers exposed to noise only 81 (group 1) and also noise and chemicals 71 (group 2). Age 18-50 years. 14 hour rest period before testing. AC, BC, SRT, SRS was done. Working for a period of 3-20 years.	Greater hearing loss in group 2 (18.3%) than group 1 (6%). Chemicals found were styrene, resins and cobalt.	Group 2 had a proportionally higher hearing loss than group 1.	Botelho, Paz, Gonçalves, & Frota, 2009
7	2010	Iran	Combined effects of ototoxic solvents and noise on hearing in automobile plant workers in Iran	Organic Solvents and Noise	To evaluate the effects of occupational exposure to noise and mixed organic solvents on hearing loss in car manufacture workers	Cross sectional design. Automobile plant. All workers who worked for more than 6 months. All male. 164 in old paint shop (noise and mixed solvents at high concentration levels). 104 new (noise and mixed solvents at low concentration levels). 173 assembly shop (noise only). pure-tone audiometry was done.	Solvents found were xylene, toluene, benzene, tetrachloroethylene and acetone. High frequency hearing loss was more common in workers exposed to noise and mixed solvents.	Combined exposure to mixed solvents and noise can exacerbate hearing loss.	Mohammadi, Labbafinejad, & Attarchi, 2010
8	2005	Brazil	Audiometric findings in petrochemical workers exposed to noise and chemical agents	Mixed solvents	To investigate the occurrence of hearing loss among workers of a petrochemical industry during a period of five years.	The records of environmental noise and solvents measurements and the results of annual audiometry performed by the company were examined. 2 groups: group 1 were workers exposed to solvents and noise and group 2 were workers exposed only to noise.	Despite the low exposures to solvents and a moderate exposure to noise, 45.3% of workers had hearing losses and 29.6% had threshold shifts.	This study suggests the necessity for reviewing the preventive measurements adopted by the company studied for eliminating the occurrence of hearing losses and standard threshold shift.	Barba, Jurkiewicz, Zeigelboim, de Oliveira, & Belle, 2005
9	2014	Brazil	Auditory Effects of Exposure to Noise and Solvents: A Comparative Study	Solvents	To evaluate the effects of the combined exposure to noise and solvents on hearing in workers.	A transversal retrospective cohort study was performed. The sample (198) was divided into four groups: the noise group, exposed only to noise; the noise and solvents group, exposed to noise and solvents; the noise control group and noise and solvents control group, no exposure.	The noise group and noise and solvent group had worse thresholds than their respective control groups. Females were less susceptible to noise than males; however, when simultaneously exposed to solvents, hearing was affected in a similar way. The 40- to 49-year-old age group was significantly worse in the auditory thresholds.	The results observed in this study indicate that simultaneous exposure to noise and solvents can damage the peripheral auditory system.	Lobato, De Lacerda, Gonçalves, & Coifman, 2014
10	2013	USA	Evaluation of the effects of exposure to organic solvents and hazardous	Organic solvents	To evaluate the risk for hearing loss among Air Force Reserve personnel exposed to	Data were collected retrospectively from existing audiometric examinations, industrial hygiene documentation. Four general exposure profiles were sought: Noise with	Followed for an average of 3.2 years, 9.2% of the study subjects had hearing loss in at least one ear. Increasing age and each year of follow-up time were significantly associated with hearing	Workers who are exposed to increasing levels of noise gradually lose hearing sensitivity over time.	Hughes & Hunting, 2013

			noise among US Air Force Reserve personnel		occupational noise with and without exposures to toluene, styrene, xylene, benzene, and JP-8 (jet fuel).	solvents, noise alone, solvents alone and neither noise nor solvents. Workplaces jobs included aircraft maintenance, flight line operations, air operations (aircrew), plumbing, electrical, carpentry, painting, heating, ventilation and air conditioning, warehouse operations, vehicle maintenance, security and fire fighting. The study population consisted of 503 workers from two Air Force Reserve sites. 41 subjects did not meet the study inclusion criteria.	loss. Low and moderate solvent exposures were not associated with hearing loss.		
11	2010	Egypt	Health hazards among a sample of workers exposed to a combination of noise and organic solvents in a fermentation factory in Egypt	Organic solvents	To study the risk of hearing loss among a sample of fermentation plant workers exposed to both noise and a mixture of organic solvents.	The exposed group consisted of 110 workers in a fermentation plant divided into two groups. Group A (50 workers,) exposed to noise only, group B (60 workers) exposed to noise and mixture of organic solvents, The control group (group C; 30 workers) were neither exposed to noise nor organic solvents. All studied sample were subjected to complete medical examination and audiometric examination using pure tone Audiometer.	Noise level was comparable in groups A&B but significantly higher than in control work places. Thirty six percent of exposed workers suffered from hearing loss versus 3.3 percent in the control group. Hearing loss was significantly higher among group B (24%) than group A (18%). Results showed that both exposed groups had higher hearing loss than normal control.	Workers exposed to both noise and organic solvents suffered from the highest proportion of hearing loss compared to those exposed to noise alone.	Rizk & Sharaf, 2010
12	2003	Taiwan	Hearing Loss in Workers Exposed to Carbon Disulfide and Noise	Carbon disulphide	To investigate hearing loss for workers exposed simultaneously to carbon disulphide (CS ₂) and noise, compared with workers with noise exposure only and workers with low noise and no CS ₂ exposure.	131 men with exposure to noise and CS ₂ in a viscose rayon plant. These men were compared with 105 men in the adhesive tape and electronic industries who were exposed to noise only and with 110 men employed in the administrative office of the rayon plant who were exposed to low noise and no CS ₂ .	Results showed a prevalence of hearing loss of > 25 dB hearing loss in rayon workers (67.9%) was much higher than that in administrative workers (23.6%) and in the adhesive tape and electronic industrial workers (32.4%). Hearing loss occurred mainly for speech frequencies of 0.5, 1, and 2 kHz.	The study suggests that CS ₂ exposure enhances human hearing loss in a noisy environment and mainly affects hearing in lower frequencies.	Chang, Shih, Chou, Chen, Chang, & Sung, 2003
13	2012	Egypt	Effect of combined occupational exposure to noise and organic solvents on hearing	Mixture of organic solvents	To evaluate the hearing of workers exposed to both noise and a mixture of organic solvents at concentrations anticipated as safe.	The study comprised of three groups. The first one included 70 workers exposed to noise only, the second group consisted of 93 workers exposed to organic solvents and noise, and the control group included 59 individuals exposed to neither noise nor organic solvents. Questionnaires were given to workers; Otoscopic examinations were conducted as well	No statistically significant difference between the two exposed groups as regards the duration of exposure. There was a highly statistically significant difference between the two exposed groups as regards the different types of hearing. The difference between the two groups was statistically significant regarding this type of hearing impairment. There was a positive	It is recommended that in the case of combined exposure, noise and solvent levels should be lowered than the permissible limits recommended for either alone.	Metwally, Aziz, Mahdy-Abdallah, Said AbdelGelil, & El-Tahlawy, 2012

						as pure tone audiometry.	significant correlation between hearing impairment and duration of exposure in the two exposed groups.		
--	--	--	--	--	--	--------------------------	--	--	--

Abbreviations used: DP (Distortion Product)- SRS (Speech Recognition Score)- VNG (Videonystagmography)- ppm (parts per million)- USA (United States of America)- AC (Air Conduction)- BC (bone Conduction)- SRT (speech Reception Testing)- OAEs (Otoacoustic Emissions)- ABR (Auditory Brainstem Response)

APPENDIX D



9 June 2015

Mrs Faatima Nakhooa 208502321
School of Health Sciences-Audiology
Westville Campus

Dear Mrs Nakhooa

Protocol reference number: HSS/0637/015M

Project title: The effects of combined exposure of solvents and noise on auditory function-a systematic review

Full Approval – No Risk / Exempt Application

In response to your application received on 3 June 2015, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted FULL APPROVAL.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

Dr Shamila Naidoo (Deputy Chair)
Humanities & Social Sciences Ethics Committee

/pm

Cc Supervisor: Mrs Samantha Govender
Cc Academic Leader Research: Professor Johan Van Heerden
Cc School Administrator: Ms P Nene

Humanities & Social Sciences Research Ethics Committee

Dr Shenuka Singh (Chair)

Westville Campus, Govan Mbeki Building

Postal Address: Private Bag X54001, Durban 4000

Telephone: +27 (0) 31 260 4000/4001 Facsimile: +27 (0) 31 260 4000 Email: shenuka@ukzn.ac.za / svmamm@ukzn.ac.za / nehuno@ukzn.ac.za

Website: www.ukzn.ac.za



Franchising Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

APPENDIX E

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES
Tel: 031 260 7438/8986
Fax: 031 260 7622
E-mail: sitholep2@ukzn.ac.za
E-mail: naidoor1@ukzn.ac.za



Date: 19/01/2015

To: Manager at Vila Footwear industry

Re: permission to conduct masters study in industry

I, Faatima Nakhoda, under the supervision of Mrs. S. Govender, am doing research towards my masters degree. My research focuses on **THE EFFECT OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION.**

In order for me to gather data for my study, I would need to conduct various audiological tests with workers employed at this industry. I request your permission to allow me to carry out a questionnaire as well as audiometric testing on workers in this industry.

Initially plan to meet with the managerial team of the company to conduct a presentation on the background and purpose of the study. I will then arrange to meet with the workers and they will be informed of the study. Recruitment posters will be placed around the industry inviting workers to participate. At the end of this session, workers will be given informational pamphlets regarding occupational hearing loss and protection of hearing within a working environment.

Workers that are exposed to noise and solvents will be expected to fill out a self-administered questionnaire, which should take approximately 10 minutes. Thereafter, those who meet the criteria will be chosen to be participants in this study. They will be required to undergo a hearing evaluation which consists of 4 very simple tests. The entire procedure will last no longer than 45 minutes.

Workers will be informed about the study through an information document. They will also be requested to sign an informed consent document. Confidentiality of the information and

identities of workers is guaranteed. The workers will be clearly explained that the testing is free as well as no incentives will be given for participation in the study. Lastly, all workers need to be informed about the results of the tests and if any test result warrants further referral, then recommendations will be provided to the workers (please see below for summary of steps to be conducted).

If the company grants me permission to base my study in their factory, please sign below.

I would be willing to formally meet with managers upon request.

I look forward to corresponding with you and will highly appreciate your participation.

Should you have any further enquiries or concerns, you may contact my supervisor, Mrs S. Govender (Tel. No.: 031- 2607438 or email: govenders2@ukzn.ac.za) or Faatima Nakhoođa 072 032 7005 or email: fiima.nakhoođa@gmail.com].

Yours sincerely



Faatima Nakhoođa
Researcher



Manager

DISCIPLINE OF AUDIOLOGY
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Fax: 031 260 7622
E-mail: sitholep2@ukzn.ac.za
E-mail: naidoor1@ukzn.ac.za



UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

Date: 23-04-14

To: Manager at Paints industry

Re: permission to conduct masters study in industry

I, Faatima Nakhooa, under the supervision of Mrs. S. Govender, am doing research towards my masters degree. My research focuses on **THE EFFECT OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION.**

In order for me to gather data for my study, I would need to conduct various audiological tests with workers employed at this industry. I request your permission to allow me to carry out a questionnaire as well as audiometric testing on workers in this industry.

Initially plan to meet with the managerial team of the company to conduct a presentation on the background and purpose of the study. I will then arrange to meet with the workers and they will be informed of the study. Recruitment posters will be placed around the industry inviting workers to participate. At the end of this session, workers will be given informational pamphlets regarding occupational hearing loss and protection of hearing within a working environment.

Workers that are exposed to noise and solvents will be expected to fill out a self-administered questionnaire, which should take approximately 10 minutes. Thereafter, those who meet the criteria will be chosen to be participants in this study. They will be required to undergo a hearing evaluation which consists of 4 very simple tests. The entire procedure will last no longer than 45 minutes. I will be conducting the entire procedure in 5 days.

Workers will be informed about the study through an information document. They will also be requested to sign an informed consent document. Confidentiality of the information and

identities of workers is guaranteed. The workers will be clearly explained that the testing is free as well as no incentives will be given for participation in the study. Lastly, all workers need to be informed about the results of the tests and if any test result warrants further referral, then recommendations will be provided to the workers (please see below for summary of steps to be conducted).

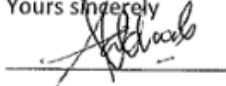
If the company grants me permission to base my study in their factory, please sign below.

I would be willing to formally meet with managers upon request.

I look forward to corresponding with you and will highly appreciate your participation.

Should you have any further enquiries or concerns, you may contact my supervisor, Mrs S. Govender (Tel. No.: 031- 2607438 or email: govenders2@ukzn.ac.za) or Faatima Nakhooda 072 032 7005 or email: tima.nakhooda@gmail.com).

Yours sincerely



Faatima Nakhooda
Researcher


Manager



South Africa
 Durban: 81 Sparks Road, Overport
 Tel: +27 31 307 8389 / 031 207 1199 - Fax: +27 31 656 5624
 Johannesburg: 41 Pinner Road, Midrand
 Tel: +27 010 224 0410
 Zimbabwe:
 Pro Star Paints - Pvt Ltd
 671A Bedford Road, Light Industrial Estate, Gwelo, Zimbabwe
 Tel / Fax: +263 054228744
 Postal Address: P.O. Box 70061, Durban, Republic of South Africa, 4007

I Vergan Kumar grant permission for the researcher to conduct the above mentioned masters study at the industry specified above.

Permission for the above request granted by:

Signature:

V. KUMAR

Date:

17.02.15

Kind Regards

Vergan Kumar
 Member

084 7986423
 031 2079195



info@prostarpaints.co.za - www.prostarpaints.co.za

Manufacturers of Pure Quality Architectural & Industrial Coatings

APPENDIX F

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES
Tel: 031 260 7438/8986
Fax: 031 260 7622
E-mail: sitholep2@ukzn.ac.za
E-mail: naidoor1@ukzn.ac.za



Dear Participant,

Thank you for consenting to take part in this research study towards my masters degree entitled, “THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION- A PILOT STUDY”. Before any testing can be conducted, you are required to please fill in this questionnaire. Should you have any difficulties understanding any of the questions, please feel free to ask for clarification.

Please take note that all information will be kept strictly confidential. Additional information may be obtained from your work file as well as from the consulting occupational health nurse.

Thank you

Section 1: Biographical information:

Research participant No: _____ (To be filled in by the researcher)

Age: _____ Gender: _____ Race: _____

Contact No/s: _____ / _____

Section 2: Medical History:

2.1. If you have any of the following, tick yes or no in the answer box below:

Do you have any of the following conditions:	Yes	No
Diabetes Mellitus		
Hypertension		
Cardiovascular disease		
Renal disease		
Cancer		
HIV		
TB		

2.2. Have you had any operations in the past and if so, please state reason.

Yes	No
-----	----

2.3. Have you had any injuries to your head or neck? If so, please describe.

Yes	No
-----	----

2.4. Are you on any medication? If yes, what medication are you on?

Yes	No
-----	----

Section 3: Hearing history:

3.1. Do you have a hearing problem? If yes, please describe the condition.

Yes	No
-----	----

3.2. If you answered yes above, then do you think the hearing problem developed before or after you were employed at this industry?

3.3. Did you have your hearing tested previously? If so, what were the results?

Yes	No
-----	----

3.4. Do you have a family history of hearing loss?

Yes	No
-----	----

3.5. Do you currently experience any of the following:	YES /NO
Middle ear infection	
Tinnitus (Ringing sound in the ear)	
Vertigo (Dizziness)	
Balance problems	
Discharging ears	

Section 4: Employment History:

4.1. What is your current employment?

4.2. Have you ever been in a job which has exposed to you high levels of noise? If so, please describe the job.

Yes	No
-----	----

Section 5: General:

5.1. Do you have any hobbies eg: shooting, frequent clubbing etc, which could have an impact on your hearing?

Yes	No
-----	----

5.2. Do you smoke? If yes, how many cigarettes a day do you smoke on average?

Yes	No
-----	----

5.3. General information:

“I, the undersigned, hereby acknowledge that all information provided above is true. I further understand that my information will be kept confidential. I grant permission to have my worker file reviewed by the researcher.”

Participant signature

Thank you for taking the time to fill out this questionnaire.
Adapted from: Govender, Govender & Matthews (2010)

DISCIPLINE OF AUDIOLOGY
 SCHOOL OF HEALTH SCIENCES
 Tel: 031 260 7438/8986
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 E-mail: sitholep2@ukzn.ac.za
 E-mail: naidoor1@ukzn.ac.za



Muhlanganyeli Othandekayo,

Ngiyabonga ngokunginika invume yokuba ube ingxenye yalolucwaningo oluphathelele nezifundo zami zobungcweti olumayelana “**IMIPHUMELA YOKETSHEZI OLUNCIBILIKAYO NOMSINDO ODLULELE MAQONDANA NOKUSEBENZA KWEZINDLEBE KUBASEBENZI BASEZIMONINI**”. Ngaphambili kokuba siqale lesisivivinyo ngiyacela ukuba uqale uphendule loluhlelo lemibuzo. Uma kwenzeka uhlangabezana nemibuzo ongayiqondi, ngiyacela ungasabi ukungibuza ngalowomubuzo owuthola unzima ukuze ngikucacisele ngawo kabazi. Ngcela ukukuqiniseka ukuthi lonke ulwazi ongiphalona kulolugcwaningo luzohlala luyimfihlo. Ulwazi olongeziwe luzotholakala kusomqulu wakho, nakusomhlengikazi onakekela osomqulukazi wabasebenzi.
 Ngiyabonga.

Isigaba 1: Imininingwane ngelunga:

Inombolo yabazibandakanya kulolucwaningo: _____ (igcwaliswa umucwaningi)

Iminyaka: _____ ubulili: _____ Uhlanga: _____
 Izinombolo zocingo: _____ / _____

Isigaba 2: Umlando ngokweshwa:

2.1. Phendula ngokuthi yebo noma cha kulelibhoxisi elingenzansi:

Ngabe unakho yini lokhu okulandelayo:	Yebo	Cha
Isifo sashukela		
Ingcindezi		
Isifo senhliziyo		
Isifo so-renal		
Umdlavuza		
HIV		
TB		

2.2. Usake wahlinzwa ngaphambilini? Uma uthi yebo, ngiyacela uchaze isizathu salokho.

Yebo	Cha
------	-----

2.3. Wake waba nokulimala ekhanda noma emuqaleni? Uma uthi yebo, ngiyacela uchaze kabanzi ngokulimala kwakho.

Yebo	Cha
------	-----

2.4. Ingabe nawe kunoma iyiphi imithi? Uma yebo, yini imithi na on?

Yebo	Cha
------	-----

Isigaba 3: Umlando wokuzwa

3.1. Ingaba unayo inking yokuzwa? Uma uthi yeo, ngcela uchaze kabanzi ngesimo sakho.

Yebo	Cha
------	-----

3.2. Uma uphendule ngoyebo ngenhla, ucabanga ukuthi lenkinga yokuzwa iqale ngemumva noma emva kokuba usuqashiwe kwezohwebo?

3.3. Usake wakuhlolelwa ukuzwa kwangaphambilini? Uma uthi yebo, yathi imiphumela?

Yebo	Cha
------	-----

3.4. Ninawo yini umlando womundeni wakini wokulahlekelwa ukuzwa?

Yebo	Cha
------	-----

3.5. Ingabe uyakuzwa yini lokhu okulandelayo njengamanje :	Yebo	Cha
Amagciwane asendlebeni ngaphakathi.		
Umsindo onkentezayo endlebeni phakathi		
Isiyezi		
Uketshezi olungcolile oluphuma endlebeni		

Isigaba 4: Umlando ngokuqashwa kwakho:

4.1. Imuphi umsebenzi owenza njengamanje?

4.2. Wake wasebenza endaweni enomusindo odlulele? Uma kunjalo, ngcela uwuchaze lomsebenzi.

Yebo	Cha
------	-----

Isigaba 5: Okujwayelekile

5.1. Hloboni yomusebenzi owenzayo wokuzilibazisa isibonelo: ukudubula, uhamba amadisco, ingaba nomuthelela oyimbangela yokuthi ungezwa?

Yebo	Cha
------	-----

5.2. Uyabhema?Uma yebo, bangaki ugwayi ngosuku ubhema ngokwesilinganiso?

Yebo	Cha
------	-----

5.3. Ulwazi olujwayelekile:


“Mina ngyavuma futhi ngiyaqonda ukuthi lonke lolwazi enginikeze lona luyiqiniso. Futhi ngyazi ukuthi konke engikushilo kuyogcinwa kuyimfihlo. Nginika invume ukuthi usomqulu wami wolwazi ucwaningwe ngaba nhlololwazi.”

Igama lomuntu obhalwe nguye. (Sayina)

Ngyabonga ngesikhathisakho osithathile ogwalisa leliphepha elinohlelo lwemibuzo.


Kucashunwe ku: Govender, Govender & Matthews (2010)

APPENDIX G



UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

THE EFFECTS OF OCCUPATIONAL
EXPOSURE TO CHEMICAL SOLVENTS
ON AUDITORY FUNCTION- A PILOT
STUDY



UKZN INSPIRING GREATNESS

MASTERS PROJECT

Researcher- Faatima
Nakhooda

Supervisor-
Samantha Govender

Topic- THE EFFECTS OF
OCCUPATIONAL EXPOSURE
TO CHEMICAL SOLVENTS ON
AUDITORY FUNCTION- A
PILOT STUDY

UKZN INSPIRING GREATNESS

Background & Motivation

- South Africa's (SA) manufacturing industry- largest in Africa
- 1, 146 000 people employed at the end of June 2012 (StatsSA, 2012)
- SA is among the top 25 chemical-producing countries in the world
- This sector has impacts on the state of human health
- Chemicals cause irritation to the :
 - ❖ skin
 - ❖ eyes
 - ❖ respiratory tract
 - ❖ nervous system
 - ❖ internal organs such as the kidneys and liver
 - ❖ specific diseases like cancer
 - ❖ **auditory system**
- Chemical substances acts as a contributor of occupational hearing loss

UKZN INSPIRING GREATNESS

Background & Motivation cont.

- "Noise Induced Hearing Loss" (NIHL)- hearing loss due to long-term exposure to loud noise
- NIHL- one of the most renowned occupational health diseases in the world
- According to the World Health Organization, it is estimated that NIHL is accountable for **16%** of the disabling hearing loss in adults
- "Solvent-induced hearing loss" (SIHL)- hearing loss caused by solvents which are ototoxic agents

UKZN INSPIRING GREATNESS

Aim

- To profile the audiological results of a group of workers exposed to solvents in factories in KZN.

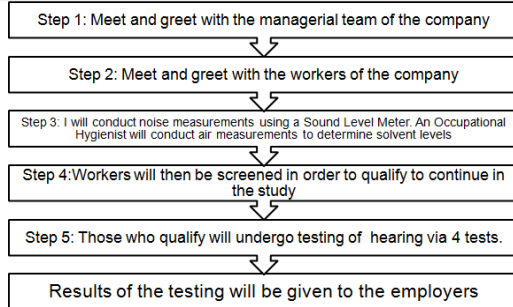
UKZN INSPIRING GREATNESS

Research process

- In order for me to gather data, I require audiological results from workers employed at this industry.
- I request your permission to allow me to carry out a questionnaire as well as audiometric testing on workers in this industry.

UKZN INSPIRING GREATNESS

Research process cont.



UKZN INSPIRING GREATNESS

- I look forward to corresponding with you and will highly appreciate your participation

Thank you

UKZN INSPIRING GREATNESS

Background & Motivation cont.

- Work-related substances include:
 - ❖ Asphyxiants
 - ❖ Pesticides
 - ❖ Metals
 - ❖ Solvents
- Long term exposure to ototoxic solvents has detrimental effects on the auditory system.
- SIHL is a fairly new concern in the field of audiology
- Serious concern for audiologists regarding NIHL but SIHL is at the **forefront** as a concern for audiologists
- Audiologists role includes facilitating the protection of hearing and rehabilitation of hearing loss

UKZN INSPIRING GREATNESS

Background & Motivation cont.

- Main users of inorganic chemicals in SA are:
 - ❖ Agriculture
 - ❖ Mining
 - ❖ Paint, plastics and pulp and paper industries
- Painting and coating constitute the largest market sector for chemicals
- Paint contains high priority organic solvents and thus the **paint industry** has been selected for this study
- Workers are exposed to these solvents which have detrimental effects on the auditory system
- Literature suggests the cumulative effects of solvents and noise on hearing
- **However**, minimal research has been conducted within South Africa

UKZN INSPIRING GREATNESS

APPENDIX H

**DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES**
Tel: 031 260 7438/8986
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E-mail: sitholep2@ukzn.ac.za
E-mail: naidoor1@ukzn.ac.za



“THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY
FUNCTION- A PILOT STUDY”

Date: _____

Dear Employee

I, FaatimaNakhoda, under the supervision of Mrs. S. Govender, am doing research towards my masters degree in Audiology on “THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION- A PILOT STUDY”. You are being invited to consider participating in a study that involves finding out if solvents and noise can affect your hearing. This study will help in determining your hearing status.

Since you meet the criteria to be a participant in this study, I request your permission to participate.

If you choose to participate in this study, you will be required to fill in a consent form stating that you agree to participate in the study. You will also be required to fill in a questionnaire providing details about your hearing and medical history. The documents will be available in both English and isiZulu. You will be required to undergo a hearing evaluation should you meet the selection criteria, which consists of 4 very simple tests. You will be guided through each test and will be given an instruction manual which will explain each test procedure clearly. The entire procedure will last no longer than an hour. This hearing evaluation will be conducted at 3 different times, the first one at the beginning of the study, the second one will be conducted 3 months later and the last one will be conducted 6 months later. At the end of the study, you will be given informational pamphlets regarding occupational hearing loss and the protection of your hearing in the work environment.

This is a risk free procedure; therefore no harm would come to you. Your participation is voluntary and you can withdraw at any point.

Benefits of participation include a free hearing evaluation. Should you fail the hearing evaluation; appropriate referrals will be made. Complete participation will contribute to acquiring important clinical data for the hearing test interpretation.

You will not be required to pay for any services. You will be required to travel to the University of KZN (Westville) for the hearing test and transport will be provided. You will be required to sign an indemnity form

stating that you will be transported under your own risk and the researcher will not be held liable for anything that may happen. There will be tea and snacks available for you during the testing procedure.

For the purpose of transcribing your results, your results will be printed. However, all information from the research will be kept strictly confidential. All results will be presented in the study with codes and numbers, with no reference to names, and the data will be presented to research supervisors in a similar manner.

An individual who speaks your language will be available to address your concerns on the day of the test.

This study has been ethically reviewed and approved by the UKZN Biomedical research Ethics Committee (approval number_____).

Should you have any further enquiries or concerns, you may contact my supervisor, Mrs S. Govender (Tel. No.: 031- 2607438 or email: govenders2@ukzn.ac.za) or Faatima Nakhooda (Tel. No.: 072 032 7005 or email: tima.nakhooda@gmail.com) or the UKZN Biomedical Research Ethics Committee, contact details as follows:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban

4000

KwaZulu-Natal, SOUTH AFRICA

Tel: +27 31 2604769 - Fax: +27 31 2604609

Email: BREC@ukzn.ac.za

Yours sincerely

Faatima Nakhooda (Researcher)

Date

Samantha Govender (Researcher Supervisor)

Date

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES

Tel: 031 260 7438/8986

Fax: 031 260 7622

E-mail: sitholep2@ukzn.ac.za

E-mail: naidoor1@ukzn.ac.za



**Imiphume layoke tshezioluncibilikayonomsindoodlulelemaqondananokusebenzakwezindle bekub
asebenzibasezimonini**

Muhlanganye liOthande kayo,

Mina, Faatima Nakhooda, ngaphansikokuqondisa u S. Govender, ngenzaucwaningomaqondanamasters degree lwami Audiology on "IMIPHUMELA YOKETSHEZI OLUNCIBILIKAYO NOMSINDO ODLULELE MAQONDANA NOKUSEBENZA KWEZINDLEBE KUBASEBENZI BASEZIMONINI". Wenabayacelwaukubabacabangeleiqhazaocwaningweniehilelaukutholaukuthiuke tshezinomsindokungathintaukuzwakwako. Lolucwaningokuzozaekunqumeniisimosakhokuzwa. Kusukelauhlangananenqubokubaabeumhlanganye likulolucwaningo, I ziceleimvumeyakhokuzeiqhaza.

Uma ukhethaukuhlanguyelakulolucwaningo, kuzodingekaukubaugcwalise ifomulokuvumaechazaukuthiuyavume lanaukuhlanguyelacwaningo. Uyot holafuthiukuthikudingekaukubaugcwaliselemibuzoenikeza imininin gwaneukuzwayakhokanyenomland obezokwelapha. Imibhaloizotholakalakokubili isiNgesi isiziZulu. Kuzodingekaukubaiibhekane nokuhlola ozwayookufaneleihlangabezaneiselection, esakhiwa 4 izivivinyosilula. Uyotholaukuqondiswangokusebenzisaitestngasinyefuthiuyonikezwaimanualimfundoo kuzobeachazeinquboyokuhlolangamunyenkokucacile. Inquboephelleliyo hla laengasekhokukakwehora .Lokhunokuhlolaozwayoizobanjelwa 3 izikhathiezahlukeno, owokuqalaequqalenicwaningo, lowoyesibilikuzokwenziwangemvakwezinyanga 3 futhiwabaowokugcinakuzokwenziwaNgemvakwezinyanga 6. Ekupheleni kwesifundo, uzonikezwa ulwazi amapheshanama yelanaemsebenzininokulahleke lwaukuzwakanyeuku vike lwaukuzw alwakhoimveloemsebenzini.

Lena ubungoziinquboufree; Ngakho keakukhoingozibabefikakini.

Ukuhlanganyelawenungokuzithandelafuthiungakwaziahoxengasiphiphuzu.

Izinzuzoiqhazazihlanganisaukuhlolwaufreekwecala. Uma uhlulekaukuhlolwaukuzwa;

ukudluliselwaafanelezizokwenziwa. Sekugcineniiqhazakuyobanomthele layokuzuzaidathazokwelaphae zibalulekileukuze incazelokuzwaitest.

Ngekekudingekaukubaakhokhelenomayimuphiizinsizakalo. Kuzodingekaukuba aye University of KZN (Westville) itestezindlebeninezokuthuthazizoni

kezwa. Kuzodingekaukubaasayineifomulokumiswaeshokuthiwenauzobeathuthwengaphansingentand oyakhokanyeumcwaningengekeozobaakhokhenomayiniengaseyenzeke. Kuyobakhona itiyengadlaetho lakalayongesikhathiinqubosokuhlola.

Ngenhlosoukuguqule laimiphume layakho, imiphumelayakhoesizophrintwa. Nokho,

yonkeimininingwane kusukela locwaningouzobekugcinwakuyimfihlongokuphelele. Zonke imiphume lai zokwethulwaocwaningwenikanyeamakhodikanyenezinombolo, kungekhoebhekiselaamagama, kantiidathauzokwethulwaukucwaningaabaqondisingendlelaefanayo.

Umuntuokhuluma ulimilwakho izotholakalabayenzenga lokhookukhathazayongosukuitest.

Lolucwaningoiyengobulungiswakubuyekezwefuthikugunyazwe UKZN Biomedical Research Ethics Committee (ukuvunyelwa number_____).

Kufaneleuneminyeimibuzookwengeziwenomaukukhathazeka, ungaxhumananomphathiwami, Mrs S. Govender (Tel No.: 031- 2607438 noma i-imeyili: Govenders2@ukzn.ac.za).

NobeFaatimaNakhooda (Tel No .: 072 032 7005 or email: tima.nakhooda@gmail.com) noma UKZN
Biomedical Research Ethics Committee, imininingwaneyokuxhumanakanje:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban

4000

Tel: +27 31 2604769 - Fax: +27 31 2604609

Email: [BREC@ukzn.ac.za](mailto: BREC@ukzn.ac.za)

FaatimaNakhooda

Umcwaningi

Usuku

Samantha Govender

UmcwaningiInduna

Usuku

ATTENTION WORKERS



Are you exposed to chemicals?

Are you between 18-50 years?

Would you be
prepared to

assist with a masters research project that
is exploring workers in industry and their
hearing?

If you are interested, contact:
FAATIMA NAKHOODA ON:
072 032 7005



APPENDIX J

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES
Tel: 031 260 7438/8986
Fax: 031 260 7622
E-mail: sitholep2@ukzn.ac.za
E-mail: naidoor1@ukzn.ac.za



“THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON
AUDITORY FUNCTION- A PILOT STUDY”

Dear participant,

Thank you for your willingness to participate in this research study toward my masters degree in Audiology. Please read the following information and sign below. Should you have any questions, please do not hesitate to ask me.

I _____ (full name of participant) have been informed about the study entitled “THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION- A PILOT STUDY” by Miss Faatima Nakhooda.

I understand the purpose and procedures of the study.

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any treatment or care that I would usually be entitled to.

I consent to having my audiological results be made available to the researcher.

If I have any further questions/concerns or queries related to the study I understand that I may contact Miss Faatima Nakhooda on 072 032 7005/ 033 413 8540.

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact::

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban

4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604769 - Fax: 27 31 2604609

Email: BREC@ukzn.ac.za

If you agree to participate, you will be given a signed copy of this document and the participant information sheet which is a written summary of the research.

An individual who speaks your language will be available to address your concerns on the day of the test.

Research participant No: _____ (To be filled in by the researcher)

The research study, including the above information, has been described to me verbally. I understand what my involvement in the study means and I voluntarily agree to participate.

Signature of Participant

Date

Signature of Witness
(Where applicable)

Date

Signature of Translator
(Where applicable)

Date

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES

Tel: 031 260 7438/8986

Fax: 031 260 7622

E-mail: sitholep2@ukzn.ac.za

E-mail: naidoor1@ukzn.ac.za



UNIVERSITY OF
KWAZULU-NATAL

INYUVESI
YAKWAZULU-NATALI

**Imiphume layoke tshezioluncibilikayonomsindoodlulelemaqondananokusebenzakwezindle bekub
asebenzibasezimonini**

Muhlanganyeli Othandekayo,

Nginyabongangokuzinikelakwakhoukubaumhlanganyeliwalolucwaningoolumayelananezifundoz
amisobungcwe tikwezocwaningongamadle be. Ngiyacelaufunde lemininingwane elandelayongenza
nsibe seuyasayina. Uma unayo imibuzo, ngice laungasabi ukungibuza.

Mina _____ (amagama aphelele omhlanganyeli)

ngazisiwengalolucwaningoolumayelane:

“Imiphume layoke tshezioluncibilikayonomsindoodlulelemaqondananokusebenzakwezindle beku
basebenzibasezimonini”, olwenziwau Nks: Faatima Nakhoda.

Nginyaqondangenjongonangendle layenquboya lolucwaningo.

Nginikeziwe ithubalokuphendula imibuzomayelanana lolucwaningongaphendulangokugculisekayo.

Ngimemezelaukuthi ukuhlalanyela kwamikulocwaningongokuphelele ngokuzithandela futhi ngingakw
aziahoxenganomaisiphisi khathingaphandle zithintaukwelashwa,

nomaukuna kekelwangokuthingangekengokuvamilekufanele one lungelo.

Nginyavumaukuthi imiphume layamiyezindle be inkikeze lwekumuncwaningi.

Uma

nginayo eminye imibuzomayelanana lolucwaningongiyazi ukuthingakwazi ukuthintau Nks Faatima Na
khoda kulezinombolo : 072 032 7005.

Futhi umanginayo eminye imibuzongama lunge lo aminjengomuhlanganyeli kulocwaningonamangikhatha
zekilemaqondananengxenye yalolucwaningonamangabancwaninginginalo ilungelolokuthinta:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban

4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604769 - Fax: 27 31 2604609

Email: BREC@ukzn.ac.za

Uma uvumaukubaubahlanganyela,
uyotholaincwadiesayiniwenephepha lemininingwane yomuhlanganye liefingqiweyocwaningo.
Umuntuokhulumaulimio lufanayonolwakhoyobeekhona ukubheke lela izinkathazo zakhongosukulezivi
vinyo.

Inomboloyomuhlanganye likulolucwaningo: _____ (igcwaliswa umucwaningi)

Lolucwaningonemininingwane ingaphezulu ichaziwe kimingomlomo. Minangiyaqondangokuthikushouk
uthini ukuzibandakanyakwamikulolucwaningongalokhongiyazinike la, ngivumaukuba umhlanganye li.

Sayina (umuhlanganyeli)


Usuku

Sayina (ufakazi)
(Lakunesidingokunesidingo)


Usuku

NOISE-INDUCED HEARING LOSS & SOLVENT INDUCED HEARING LOSS

HOW ARE WORKERS AFFECTED BY LOUD SOUNDS AND SOLVENTS?





<<<PROTECT YOUR HEARING>>>



To protect your hearing:

- Know which solvents can cause damage to your hearing (toluene, xylene, styrene etc.).
- Wear a mask when involved with chemicals
- If you suspect hearing loss, have a hearing evaluation by an audiologist (a health professional trained to measure and help individuals deal with hearing loss).

WHAT IS SOLVENT INDUCED HEARING LOSS (SIHL)?

There are certain solvents and chemicals present in industries that could cause hearing loss when inhaled.

What are the symptoms of SIHL?

- Sounds, particularly speech, may sound muffled or distorted
- Speech may become difficult to understand
- Tinnitus: a ringing or buzzing sound heard in the ears. Tinnitus can occur in conjunction with, or without a hearing loss

Can SIHL be prevented?

SIHL is preventable. Everyone should understand the hazards of solvents, particularly as a worker in an industry, as you are exposed to solvents in your work environment.

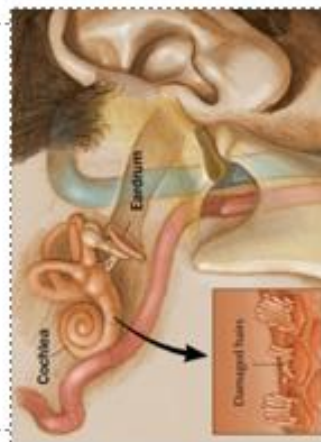
122

What is noise induced hearing loss?

loss?

When the hearing system is exposed to high-level sound over a period of time, a hearing loss develops, and this is termed as noise induced hearing loss (NIHL). There may be damaging effects on the hearing system of those individuals who engage in activities involving high-level sounds. High-level sound is very loud sounds that are produced in an industry, for example while operating machinery.

Excessive noise damages tiny sensory hair cells deep inside your ear



What are the symptoms of NIHL?

- Sounds, particularly speech, may sound muffled or distorted
- Speech may become difficult to understand
- innitus: a ringing or buzzing sound heard in the ears. This can occur in conjunction with, or without a hearing loss

Can NIHL be prevented?

NIHL is preventable. Everyone should understand the hazards of high-level sound, particularly as a worker in an industry, as you are exposed to high-level sound around machinery.



To protect your hearing:

- Know which high-level sound can cause damage (those at or above 80 decibels).
- wear earplugs or other hearing protective devices e.g. head phones when involved in a loud activity
- Be aware of hazardous noise in the environment
- If you suspect hearing loss, have a hearing evaluation by an audiologist (a health professional trained to measure and help individuals deal with hearing loss).

Types of hearing protection available:

There are many different types of hearing protection that is available on the South African markets. Below are some useful links as well as contact details of the UKZN Audiology Department in the event of any queries:

Remember
: NIHL
is
permanent
and
cannot
be
cured!

1. Impact Noise Protection for information regarding NIHL as well as available protection - info@noiseprotection.co.za
2. The South African Association of Audiologists for a list of Audiologists in South Africa - www.audiologistsa.co.za
3. Uvex for hearing protection products - www.uvex.co.za
4. 3M South Africa for ear protection products - www.solutions.3m.co.za
5. Department of Audiology at the University of KwaZulu Natal - (031) 260 7438



Iliphi uketshezi - olahlekelwe - olungenza - ukuzwa?

Kukhona uhlobo loketshezi nama izithako zemvelo esikhona kwezoqhwebho (zimbongi) ezingenza ulahlekelwe ukuzwa uma uzihogela.

Iziphi izimpawo zoketshezi olungenza - ulahlekelwe ukuzwa?

- Umsindo, ikakhulu inkulumbo ingangezwakala kahle.
- Kuyele ekutheni inkulumbo kubenzima ukuthi izwakale
- Umsindo onkentezayo ozwakala ezindlebeni. Lokhu kungenzeka kumuntu osezwa kahle noma oseqale ukulahlekelwa ukuzwa.

Ikhona yini indlela engavimba loluketshezi lungabangeli ukuthi ugcine - ungezwa?

Ikhona indlela yokuvimbele loluketshezi ukuthi lingabi imbangela yokulahlekelwa ukuzwa. Bonke abantu kufanele bazi ngobungozi oketshezi olincibilikisayo, ikakhulukazi abasebenzi abasebenzisa uketshezi olincibilikisayo ezimbombini noma kwezoqhwebho.

Ukuvikela ukuzwakakho:

Ibanohwazi olufanele ngezinkhondo zoketshezi olincibilikisayo olungaba yimbangela yokulahlekelwa ukuzwa.

Gqoka isivikela mlomo (mask) uma usebenza ngezithako.

Uma usola ukudji ulahlekelwa ukuzwa, iya ukohlolwa ukungezwa kudokotela wezindlebe ovuvopheshe, futhi oqeqeshwe labanzi ngokulinganisa nokusiza abantu bakwazi ukubhelana nokulahlekelwa ukuzwa.



**UKULAHLEKELWA UKUZWA
NGENHLA YOMSINDO
KANYE NOKULAHLEKELWA
UKUZWA OKUBANGWA
UKUHLANGANA NOKETSHEZI**

**ABASEBENZI
BAHLUKUMEZEKA
KANJANI IMISINDO
ESEZINGENI
ELIPHEZULU?**



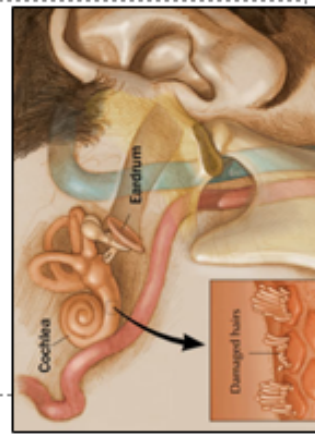
<<<VIKELA UHUZWA KWANHO>>>



Luyini uhlobo lokulahlekelwa ukuzwa olubangwa umsindo omkhulu?

Uma uchitha isikhathi sakho esiningi endaweni enomusindo omkhulu, emvakweni esikhathi eside ungazibona usulalekelwa ukuzwa, lokhu kubizwa ngokuthi ukungazwa yimbangela yomusindo omkhulu (noise induced hearing loss [NIHL]). Kukhona umonakalo odalekayo kwindlebe nokusebenzakayo kubantu abahlala kakhulu noma abasebenzela kwindawo enomusindo omkhulu. Ezinye izimbongi noma izindawo zohwebo zinxaxo lemitsondo emikhulu edlalwa kuzo izindawo yokusebenzela etholakala kuzo izindawo zokuthweba eyimbangela yokulahlekelwa ukuzwa.

Umsindo omkhulu odlulekayo uyimbangela yomonakalo owenzakala phakathi endlebeni



Yini izimpawo zokulahlekelwa ukuzwa olubangwa umsindo odlulekayo?

Umsindo, ikakhulu inkulumbo ingenzakala ibhivikile ingezwakali kahle...

- Kubanzima ukuzwa ibhu luno.
- Umsindo onkenterazo ozwakala ezindlebeni. Lokhu kuncenzeka kuhlangene nokulahlekelwa ukuzwa noma kungelona ukulahlekelwa ukuzwa.

Ikhona yini indlela yokuyimbela ukungazwa olubangwa umsindo omkhulu?

Ikhona indlela yokuyimbela umsindo omkhulu ukuthi uyabangeli ukulahlekelwa ukuzwa. Bonke abantu kumele baqonde ngobungozi bokuhlala endaweni enomusindo odlulele, ikakhulukazi abasebenzi abasebenzela ezindaweni zohwebo ezinomusindo omkhulu odalwa imishini yokusebenzela, obangela ukulahlekelwa ukuzwa.

Ukuyabuluzwa

- Yazi ngezina lomusindo omkhulu ongayimbangela yokudala ukungazwa. Ilowo msindo izinzalwawo elingaphezulu noma eli ngu80 decibels
- Gqoka isivimbo ezindlebe esingavikele izindlebezakho uma usebenza endaweni enomusindo omkhulu.
- Qaphela izindawo ezinomungozi bokuba nomusindo odlulele.
- Uma usola ukulahlekelwa ukuzwa, hamba uyekohlolwa ukuzwa kudokotela wezindlebe oqesheho nobuchushhe ekulinganiseni nokusiza abantu bamelane nokulahlekelwa ukuzwa.

Izinhlobo zezivikela kuzwa:

Ziningi izivikela kuzwa ezitholakala ezimakethe zaseMzantsi Afrika. Ngezansi kukhona imininqwane nezinombolo zase unuyvesi kwazulu natali yegumbi lokuhlola izindlebe umakukhona imibuzo:

- Impact Noise Protection for information regarding NIHL as well as available protection - info@noiseprotection.co.za
- The South African Association of Audiologists for a list of Audiologists in South Africa- www.audiologysa.co.za
- Uvex for hearing protection products- www.uvex.co.za
- 3M South Africa for ear protection products- www.solutions.3m.co.za
- Department of Audiology at the University of KwaZulu Natal- (031) 260 7438



APPENDIX L

1. Participant No. _____

2. Age: _____

3. Gender: _____

4. No of years worked _____

5. Exposed to:

Noise	Solvents	Noise and solvents

6. No of hours/day exposed to:

Noise	Solvents	Noise and solvents

7. Noise protection: Yes/No

8. Solvent protection: Yes/ No

9. Otoscopic:

EAR	NAD	WAX	DISCHARGE	OTHER
R				
L				

10. Tympanometry:

EAR	TYPE A	TYPE B	TYPE C	TYPE D
R				
L				

11. Reflexes:

EAR	WNL	ONL
R		
L		

12. Pure tones:

EAR	NORM 0-25dB	MILD 26-40dB	MOD 41-55dB	MOD-SEV 56-70dB	SEVERE 71-90dB	PROFOUND 91+
R						
L						

13. OAEs:

EAR	PASS	FAIL
R		
L		

APPENDIX M

1. Name of worker: _____

2. Age: _____

RESULTS:

3. Otoscopy:

	EAR	NAD	WAX	DISCHARGE	OTHER
R					
L					

4. Tympanometry:

	EAR	TYPE A	TYPE B	TYPE C	TYPE D
R					
L					

5. Reflexes:

	EAR	WNL	ONL
R			
L			

6. Pure tones:

	EAR	NORM 0-25dB	MILD 26-40dB	MOD 41-55dB	MOD-SEV 56-70dB	SEVERE 71-90dB	PROFOUND 91+
R							
L							

7. OAEs:

	EAR	PASS	FAIL
R			
L			

8. Pass _____

Fail _____

RECOMMENDATIONS:

Wax management	
Diagnostic audiometry assessment	
Medical management	

Sincerely

Faatima Nakhooda- Audiologist

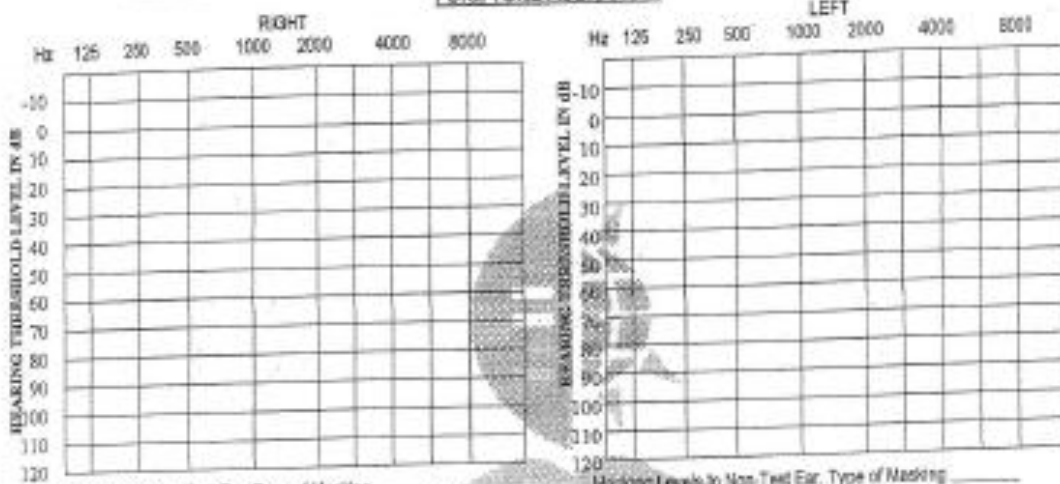
APPENDIX N

UNIVERSITY OF KWAZULU-NATAL Discipline of Audiology: Audiological Record Form

STIMULUS	Response		
	Right Red	Left Blue	Unspecified
Air Conduction	○	×	
AC Masked	△	□	
Bone Conduction	<	>	^
BC Masked			
Free Field	○	×	S
No Response (AC)	P	X	
No Response (BC)	F	B	
ONI	Could not evaluate		

Surname & Initials: _____
 File No.: _____
 Date of Birth: _____
 Contact no: _____
 Test Date: _____
 Audiologist: _____
 Test Reliability: _____
 Pure Tone Average: Right _____ dB
 Left _____ dB

PURE TONE AUDIOGRAM



Masking Levels to Non-Test Ear. Type of Masking _____

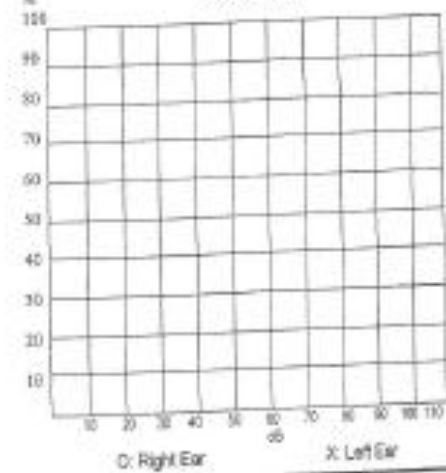
Hz	250	500	1k	2k	4k	8k
AC						
BC						

SPEECH AUDIOMETRY

EAR	SRT	MCL	TD	DR	MASKING	
					LEVEL	EAR
RIGHT						
LEFT						
FREEFIELD						

EAR	MATERIAL	dB SL	dB HL	%	MASKING	
					LEVEL	EAR
RIGHT						
LEFT						
FREE FIELD						

P.L. FUNCTION



OTOSCOPIC EXAMINATION

	No abnormalities detected	Wax	Perforated TM	Other
Right				
Left				

IMPEDANCE AUDIOMETRY

Tympanometry

See attached tympanogram RE: Type _____ LE: Type _____ ECV: RE: _____ LE: _____ SC: RE: _____ LE: _____

Acoustic Reflex Threshold Testing

Right		Frequency	Left	
Ipsilateral Reflex	Contralateral Reflex		Ipsilateral Reflex	Contralateral Reflex
		250Hz		
		500Hz		
		1000Hz		
		2000Hz		
		4000Hz		
		SDN/NN		

Acoustic Reflex Decay Test
See attached record

Ear	Positive	Negative
Right		
Left		

SPAR Prediction

Right Ear	
Left Ear	

HEARING AID INFORMATION

	Frequency	Unaided	Aided	Functional Gain	SD Score
Right	125Hz				
	250Hz				
	500Hz				
	1000Hz				
	2000Hz				
	4000Hz				
Left	125Hz				
	250Hz				
	500Hz				
	1000Hz				
	2000Hz				
	4000Hz				

OTOACOUSTIC EMISSIONS

Emission Type	Test Type Performed
Transient	OAE Diagnostic
Distortion Product	OAE Screening
Right Ear	
Left Ear	

SPECIAL TESTS

SISI

Right-% score	Frequency	Left-% score

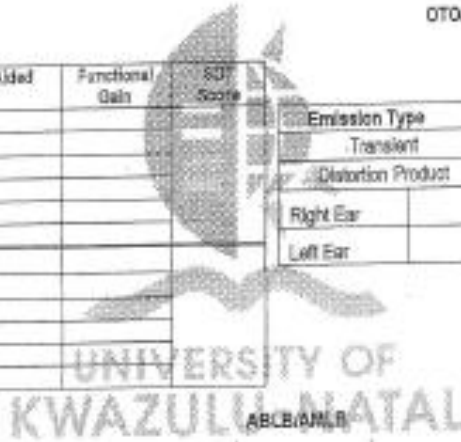
Tone Decay

Right	Frequency	Left

Reference Ear: _____
Variable Ear: _____

No recruitment	
Partial recruitment	
Complete recruitment	
De-recruitment	

Comments



APPENDIX O

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES

Tel: 031 260 7438/8986

Fax: 031 260 7622

E-mail: sitholep2@ukzn.ac.za

E-mail: naidoor1@ukzn.ac.za



UNIVERSITY OF
KWAZULU-NATAL

INYUVESI
YAKWAZULU-NATALI

August 2014

To: The Academic leader
Discipline of Audiology
College of health sciences

Re: Request for permission to use department equipment

Dear: Dr Neethle Joseph

I would first like to take this opportunity to thank you for your assistance thus far. I am an Audiology master's student at UKZN Westville Campus currently conducting research at a factory in Durban. My topic is **"THE EFFECT OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION"**.

I am awaiting ethical clearance from the Biomedical Research Ethics Committee. I have been further granted permission from the manager at the factory I will be investigating (see attached letter). In order to conduct my study, I will need to make use of the following equipment:

- Audiology sound booth (Booth 1)
- Pure tone audiometer (GSI 61)
- Immittance machine (GSI middle ear analyser)
- Otoacoustic emissions machine (Biologic Audex)
- Sound level meter

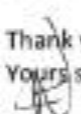
I am asking permission to utilize this equipment for a period of 6 weeks under the supervision of lecturer Samantha Govender. I will access the equipment via Samantha Govender and will utilize the equipment with utmost care as well as sign any documentation regarding indemnity/care of equipment. I will be using the equipment both on and off campus. I will inform Mr Jili each time I take equipment off campus and will ensure that the correct security measures are taken.

I will further ensure that my data collection period does not interrupt clinical sessions or student training.

Below is a section for you to sign, so that I have written consent.
Thank you for your time, it is appreciated.

Should you have any queries, please contact me on 0720327005 or my supervisor Mrs. S. Govender on 0734990703.

Thank you
Yours sincerely


Faatima Nakhooda (researcher)


Samantha Govender (supervisor)

APPENDIX P

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES

Tel: 031 260 7438/8986

Fax: 031 260 7622

E-mail: sitholep2@ukzn.ac.za

E-mail: naidoor1@ukzn.ac.za



I _____ (full name) _____ (ID / passport number) hereby indemnifies Miss _____ (the researcher) against any lawsuit, persecution and other actions that may arise during transport provide at any time or place by the researcher. My acceptance of the services is entirely at my own risk. The researcher accepts no responsibility for any damages suffered, for theft, loss, or damage to any property, or for any injury or death arising of whatsoever nature, regardless of the cause of such damages, loss, injury or death.

I declare that I understand the meaning and implications of this indemnity, which was explained to me.

Signed at _____ on this _____ day of _____ 20_____

Signature of worker

Signature of researcher
Faatima Nakhooda

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES

Tel: 031 260 7438/8986

Fax: 031 260 7622

E-mail: sitholep2@ukzn.ac.za

E-mail: naidoor1@ukzn.ac.za



Mina _____ (igama eliphelel) _____ (izinombolo zasepasini noma ezipasi lokuhamba) ngiyamuvikela ecaleni uNks _____ (umcwaningi) kungayinoma iliphi icala phambi kwenkantolo nanga yinoma isiphi isenzo esingavela phakathi kwezokuthuthwa noma ingasiphi isikhathi noma indawo yomucwaningi. Bonke ubungozi obungavela ekukusebenzeleni buyobe busemahlombe ami. Umucwaningi akanisibopho kumonakalo ongavela , ukutshontshwa, ukulahlekelwa, nomonakalo wempahla, nokulimala noma ukufa okungavela kwangayinoma iluphi uhlobo noma ngayinoma yimiphu umonakalo ukulahlekelwa, ukulimala noma ukufa.

Ngiyagomela ukuthi ngiyaqonda ngakhokonke okumayelana nalefomu yesibuyezelo, engichazelwengayo.

Isayinelwe _____ lana _____ ngalelilanga _____ 20 _____

Kusayina umsebenzi

Kusayina umcwaningi
Faatima Nakhooda

APPENDIX Q

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES

Tel: 031 260 7438/8986

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E-mail: naidoor1@ukzn.ac.za



UNIVERSITY OF
KWAZULU-NATAL

INYUVESI
YAKWAZULU-NATALI

Dear Participant

Thank you for indicating an interest in this study. This study is aimed at finding out if solvents and noise affects your hearing. In order to obtain this information we are requesting your participation. You will be required to complete the following questionnaire, which should take about 15 minutes to complete. The results obtained will be used for the study.

All information and test results will be treated with confidence by the researcher.

Your consent to participate in this project will be highly appreciated.

INSTRUCTIONS

- This questionnaire is divided into 3 sections
- You are required to answer all questions in each section
- Some questions provide options, please tick the appropriate box
- Other questions require responses/opinions, please fill in the spaces provided
- Please answer to the best of your ability
- Should you require any assistance you may contact us on the number attached

SECTION A BIOGRAPHICAL DATA

Research participant No: _____ (To be filled in by the researcher)

Language: _____

Age: _____

Date of birth: _____

Gender: _____

SECTION B HEARING CONSERVATION

1. Do you have any concerns regarding your hearing?

Yes	No
-----	----

2. Have you had a hearing test at this company?

Yes	No
-----	----

2.1. When was your last hearing test? _____

2.2. What were your results?

3. Do you use any devices to protect your hearing at work e.g. earplugs

Yes	No
-----	----

4. Have you noticed a change in your hearing over time?

Yes	No
-----	----

SECTION C
EMPLOYMENT HISTORY

1. How long have you been working at the industry?

2. How long are your shifts e.g. 3 shifts rotate on a 3 week basis?

3. How many breaks do you have and when are they?

4. Where do you spend your breaks? How far are you from noise?

5. What type of machinery do you work with?

6. Does your machinery remain on the whole day?

Yes	No
-----	----

7. Do you work with the same machine the whole day? Or do you work in other areas of the plant throughout the day?

8. Do you perform manual labour e.g. lifting, carrying etc.?

Yes	No
-----	----

If yes, can you describe what type of manual labour you perform?

9. Do you sit in front of a machine?

Yes	No
-----	----

10. Do you use a mask while you are working?

Yes	No
-----	----

11. When inhaling the chemicals, do you have a problem with:

SYMPTOMS	YES	NO
Breathing	S	
Headaches		
Dizziness		
Blurry eyes		
Other		

12. Do you know what chemicals you work with? If yes, please tick the chemicals you work with

Yes	No
-----	----

CHEMICAL	YES	NO
Xylene		
Toluene		
Styrene		
Ethyl benzene		
Other		

13. How many hours a day are you exposed to chemicals?

14. How many years have you been exposed to solvents particularly?

Thank You for completing this questionnaire

**DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES**

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E-mail: naidoor1@ukzn.ac.za



**UNIVERSITY OF
KWAZULU-NATAL**

**INYUVESI
YAKWAZULU-NATALI**

Muhlanganyeli othandekayo

Ngiyabonga ngokubamba iqaza kulolucwaningo. Lolucwaningo olumayelana nokuthola ukuthi umsindo odlulele noketshezi oluncibilikayo lunamuthelela muni ekuzweni, noma ekusebenzeni kwendlebe. Ukuze siqiniseke ukuthi lolucwaningo luyayiveza injongo yalo siyakunxusa ukuba ube ngumuhlanganyeli kulo. Kubalulekile ukuthi uphendule loluhla lwemibuzo, olungakuthatha isikhathi esingangemizuzu eyishumi nanhlano. Imiphumela ezotholakala kulo loluhla lwemibuzo iyona ezosetshenziswa kulolucwaningo.

Lonke lwazi nemiphumela yokuhlolwa kuyophathwa ngesiqiniseko sokuphenywa umcwaningi. Ngiyosithokozela kakhulu isivumelwano sakho sokuvuma, ukuba yingxenywe yalolucwaningo.

IMIYALO

- Loluhla lwemibuzo luhlukanisiwe izigaba ezintathu
- Kuyadingeka ukuba uphendule yonke imibuzo kuzozonke lezigaba
- Kweminye yalemibuzo unikeziwe uhla lwezimpendulo ongakhetha kulo, ngyacela ukuba utshengise ngophawu eceleni kwempendulo oyikhethile.
- Eminye yalemibuzo idinga imibono yakho, ngyacela ukuba uyibeke ngokufanelekile ezikheleni onikeziwe zona
- Uyacelwa ukuba uphendule yonke imibuzo ngokusemandleni akho
- Uma udinga uzizo oluthile ekuphenduleni eminye yalemibuzo, ungakwazi ukusithinta kulezinombolo zocingo onikezelwe zona kulo lolucwaningo

ISIGABA A

OKUBANDAKANYA UMHLANGANYELI

Inombolo yomuhlanganyeli kulolucwaningo : _____ (Izocwaliswa umcwaningi)

Ulimi: _____

Iminyaka: _____

Usuku lokuzalwa: _____

Ubulili: _____

ISIGABA B

UKUZWA INKULUMO

1. Ingabe unakho ukukhathazeka ngokuzwa kwakho?

Yebo	Cha
------	-----

2. Useke wahlololwa ukuzwa kule nkampani?

Yebo	Cha
------	-----

2.1. Wagcina nini ukuhlololwa ukuzwa? _____

2.2. Yabanjany imiphumela yakho?

3. Zikhona yini izinsiza ozisebenzisayo ukuze uvikele ukuzwa kwakho, kumusebenzi owenzayo. Isibonelo: isivimba msindo.

Yebo	Cha
------	-----

4. Usuke walubona ushintsho ekuzweni kwakho ngokuhamba kwesikhathi?

Yebo	Cha
------	-----

ISIGABA C
UMLANDO WAKHO KOKUSEBENZA

1. Ususebenze isikhathi esingakanani kulemboni okuyo?

2. Uthatha isikhathi esingakanani umsebenzi wakho? Isibonelo:

3. Uyanini ekhefini? Futhi uyakangaki?

4. Ulichithelaphi ikhefulakho? Usuke ukude kangakanani endaweni enomusindo odlulele?

5. Usebenzisa uhlobo olunjani lwemishini yokusebenzela emusebenzini wakho?

_____ Ingaba
lemishini osebenza ngayo ihlala ivuliwe usukulonke?

Yes	No
-----	----

6. Usebenzisa umshini ofanayo usukulonke? Noma uyayishintsha shintsha osukweini lonke?

7. Uyawaphakamisa ngezandla noma usemenzisa umshini?

Yebo	Cha
------	-----

Uma uvuma usebenzisa yiphi indlela?

8. Uhlala phambi komshini?

Yebo	Cha
------	-----

9. Uyasisebenzisa yini isivikele ngenkathi usebenza ngayo?

Yebo	Cha
------	-----

10. Uma uhongela uketshezi oluncibilikayo, uyaba yini nalezizinkinga:

IZIMPAWU	YEB	CHA
----------	-----	-----

	O	
Ukuphefumula		
Ikhanda		
Isiyezi		
Ukungaboni kahle		
Okunye		

11. Uyayazi yini imishini osebenza ngayo? Uma ngabe uyavuma, beka uphawu maqondana noketshezi oluncibilikayo osebenza ngayo.

Yebo	Cha
------	-----

UKETSHEZI OLUNCIBILIKAYO	YEB O	CHA
Xylene		
Toluene		
Styrene		
Ethyl benzene		
Okunye		

12. Mangaki amahora osukwini lana usuke usebenza ngaloluketshezi oluncibilikayo?

13. Minyaki iminyaki usendaweni enama uketshezi oluncibilikayo?

Ngiyabonga

APPENDIX R

DISCIPLINE OF AUDIOLOGY
SCHOOL OF HEALTH SCIENCES
Tel: 031 260 7438/8986
Fax: 031 260 7622
E-mail: sitholep2@ukzn.ac.za
E-mail: naidoor1@ukzn.ac.za



-

Date: 21/01/2015
Company: POS Computers

RE: PILOT STUDY

I, Faatima Nakhoda, under the supervision of Mrs. S. Govender, am doing research towards my masters degree. My research focuses on THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION- A PILOT STUDY.

In order for me to gather data for my study, I need to conduct a pilot study. Workers will be expected to fill out a self-administered questionnaire, which should take approximately 10 minutes. I request your permission to allow me to carry out a pilot study on workers in this industry.

If the company grants me permission for the above request, please sign below.
Should you have any further enquiries or concerns, you may contact my supervisor, Mrs S. Govender (Tel. No.: 031- 2607438 or email: govenders2@ukzn.ac.za) or Faatima Nakhoda 072 032 7005 or email: tima.nakhoda@gmail.com).

Yours sincerely



Faatima Nakhoda
Researcher

	<p>031 208 0691 081 786 3050 084 662 2146 poscomp@telkomsa.net</p>	<p>1 6 5</p>
<p>Computer Solutions</p>		
<ul style="list-style-type: none"> - Point of Sale - Software & Hardware (Specialists for Hardware Stores) - On Site Maintenance - Software Development - Digital Surveillance - CCTV Camera Systems - Distributors of Labels, Till Slip Rolls, - Barcode Printers - Wholesalers of Dell Ex - Lease Computers 		
		

I NaeemVanker grant permission for the researcher to conduct the above mentioned study at the company specified above.

Permission for the above request granted by: NaeemVanker

Signature:



Date:

23/01/2015

APPENDIX S

DISCIPLINE OF AUDIOLOGY
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E-mail: naidoor1@ukzn.ac.za



Dear participant

The researcher requires feedback on the questionnaire that has been completed. Please fill out the following questions to the best of your ability. Your comments will be highly appreciated.

1. How long did it take you to complete the questionnaire?

2. Did you have any difficulty understanding any of the instructions provided?
If yes, which instructions and why?

Yes	No
-----	----

3. Did you have difficulty answering any of the questions?
If yes, which questions and why?

Yes	No
-----	----

4. Was there any repetition or ambiguity in any of the questions?
If yes, which instructions and why?

Yes	No
-----	----

5. Were you able to understand the language used in the questionnaire?
If yes, which instructions and why?

Yes	No
-----	----

6. Do you have any further suggestions?

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E-mail: naidoor1@ukzn.ac.za



Muhlanganyeli Othandekayo

Umucwaningi ufuna incazelo maqondana nemibuzo oqeda ukuyiphendula. Ngiyacela uphendule lemibuzo elandelayo ngokukhulu ukuzimisela. Imibono yakho iyabongeka.

1. Kukuthathe isikhathi esingakanani ukuphendula lemibuzo?

2. Uhlangebanile nobunzima ekuqondeni eminye yalemiyalezo onikeziwe yona?
Mangabe uvuma, imiphi lowo muyalezo?

Yebo	Cha
------	-----

3. Uhlanga nile nobunzima ekuphenduleni eminye Yalemibuzo?
Mangabe uvuma, imiphi lowo mbuzo?

Yebo	Cha
------	-----

4. Ikhona yini imibuzo obona engathi iphindaphindiwe noma phindekile?
Uma uvuma, imiphi lowombuzo chaza futhi ukuthi kungani?

Yebo	Cha
------	-----

5. Ingabe ukwazile ukuqonda ulimi ulusetshenziwe kululuhlelo lemibuzo?
Uma uvuma, bekuyimuphi umubuzo chaza futhi ukuthi kungani?

Yebo	Cha
------	-----

6. Ingaba unayo yini eminye imibono?

APPENDIX T



FHI 360

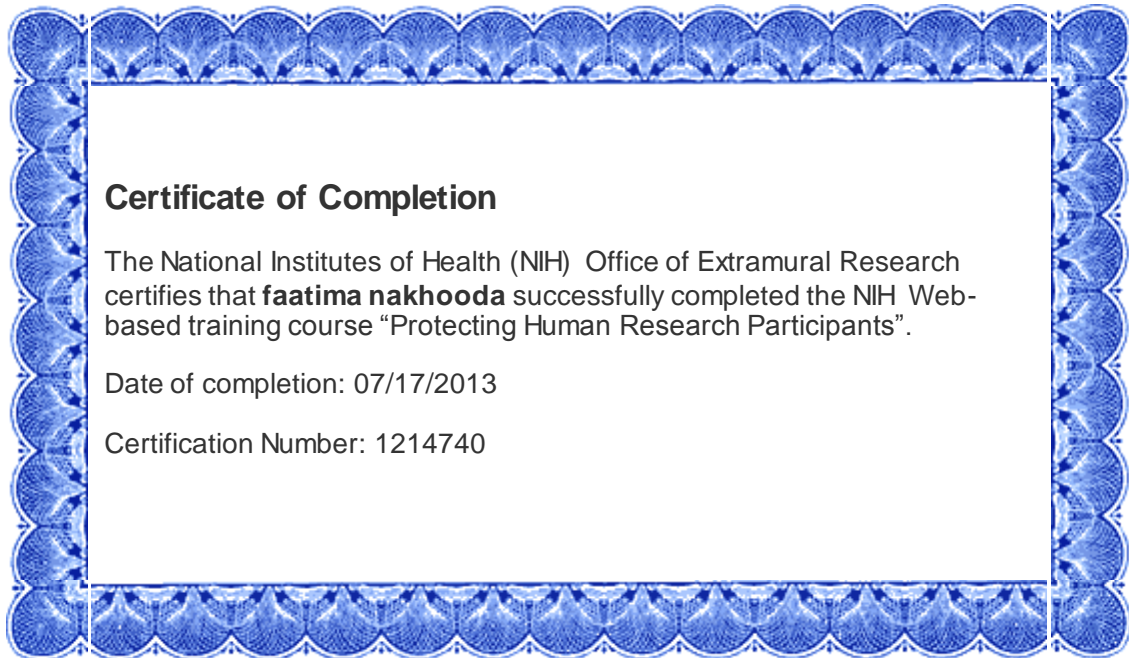
certifies that

FAATIMA NAKHOODA

has completed the

RESEARCH ETHICS TRAINING CURRICULUM

APPENDIX U



APPENDIX V



23 February 2015

Miss Faatima Nakhooda
P O Box 1339
Stanger, 4450
tima.nakhooda@gmail.com

Dear Miss Nakhooda

PROTOCOL: The effect of occupational exposure to chemical solvents on auditory function: Degree Purposes (Masters). BREC REF: BE393/14.

EXPEDITED APPLICATION

A sub-committee of the Biomedical Research Ethics Committee has considered and noted your application received on 18 August 2014.

The study was provisionally approved pending appropriate responses to queries raised. Your responses received on 19 February 2015 to queries raised on 09 February 2015 have been noted by a sub-committee of the Biomedical Research Ethics Committee. The conditions have now been met and the study is given full ethics approval.

This approval is valid for one year from 23 February 2015. To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (2004), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at <http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx>.

BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

The sub-committee's decision will be **RATIFIED** by a full Committee at its meeting taking place on 10 March 2015.

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely

Professor V Rambiritch
Deputy Chair, Biomedical Research Ethics Committee

Biomedical Research Ethics Committee

Professor D R Wassenaar (Chair)

Westville Campus, Govan Mbeki Building

Postal Address: Private Bag 354001, Durban 4003

Telephone: +27 (0) 31 260 2488 Facsimile: +27 (0) 31 260 4999 Email: brec@ukzn.ac.za

Website: <http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx>



Executive Campus ■ Edgewood ■ Howard College ■ Medical School ■ Pietermaritzburg ■ Westville

APPENDIX W

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E-mail: naidoor1@ukzn.ac.za



“THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON
AUDITORY FUNCTION- A PILOT STUDY”.

Date: _____

To: Manager at _____ industry

Re: permission to conduct masters study in industry

I, Faatima Nakhoda, under the supervision of Mrs. S. Govender, am doing research towards my masters degree. My research focuses on THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION- A PILOT STUDY.

Literature has found that solvents and noise exposure affect the auditory system in various ways including damage to the structure and function of the ear, the central and nervous system and vestibular organs. Individuals who are affected by solvents and noise could present with hearing loss, tinnitus, balance problems etc. Currently, there is minimal research in South Africa (SA) regarding the effects of solvents on auditory function, as well as limited regulations that are put into place for solvents in the workplace. The information that I obtain from the study will be used to contribute towards research in SA, assist with management of solvent induced hearing loss as well as possibly influence current legislation on solvents in the workplace in order to protect workers.

In order for me to gather data, I would need to conduct various audiological tests with workers employed at this industry. I request your permission to allow me to carry out a questionnaire as well as audiometric testing on workers in this industry.

Initially plan to meet with the managerial team of the company to conduct a presentation on the background and purpose of the study. I will then arrange to meet with the workers and they will be informed of the study. Recruitment posters will be placed around the industry inviting workers to participate. At the end of this session, workers will be given informational pamphlets regarding occupational hearing loss and protection of hearing within a working environment.

Workers that are exposed to noise and solvents will be expected to fill out a self-administered questionnaire, which should take approximately 10 minutes. Thereafter, those who meet the criteria will be chosen to be participants in this study. They will be required to undergo a hearing evaluation which consists of 4 very simple tests. The entire procedure will last no longer than 45 minutes. I will be conducting the entire procedure in 5 days.

Workers will be informed about the study through an information document. They will also be requested to sign an informed consent document. Confidentiality of the information and identities of workers is guaranteed. The workers will be clearly explained that the testing is free as well as no incentives will be given for participation in the study. Lastly, all workers need to be informed about the results of the tests and if any test result warrants further referral, then recommendations will be provided to the workers (please see below for summary of steps to be conducted).

I would be willing to formally meet with managers upon request.

I look forward to corresponding with you and will highly appreciate your participation.

Should you have any further enquiries or concerns, you may contact my supervisor, Mrs S. Govender (Tel. No.: 031- 2607438 or email: govenders2@ukzn.ac.za) or Faatima Nakhooda (Tel. No.: 033- 413 8540 or 072 032 7005 or email: tima.nakhooda@gmail.com) or the UKZN Biomedical Research Ethics Committee, contact details as follows:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban

4000

KwaZulu-Natal, SOUTH AFRICA

Tel: +27 31 2604769 - Fax: +27 31 2604609

Email: BREC@ukzn.ac.za

Yours sincerely

Faatima Nakhooda
Researcher

Date _____

Samantha Govender
Researcher Supervisor

Date _____

Step 1: The researcher will meet and greet with the managerial team of the company to conduct a PowerPoint presentation on the study.

Step 2: The researcher will meet and greet with the workers of the company.

Step 3: The researcher will consult with the company's policies, regulations and operating procedures to gain air and noise measurements to ensure that stringent measurements are applied. The researcher will also conduct noise measurements using a Sound Level Meter (SLM) in various areas of the factory at single locations and larger areas. An Occupational Hygienist will be employed by the researcher to conduct air measurements to determine solvent levels within various parts of the factory.

Step 4: Workers will then be screened in order to qualify to continue in the study, this will be done via a questionnaire and 2 tests.

Step 5: Testing of workers hearing will then be conducted via 2 tests. Workers will be transported to the UKZN Audiology Department for these tests to be conducted so that they are tested in a suitable testing environment. The researcher will make tea and snacks available for the participants during the testing procedure so that they are comfortable. These tests will be conducted on the workers day off so that the procedure will not affect a day of work.

Results of the testing will be given to the employers.

APPENDIX X

APPENDIX F: PROOF OF TRANSLATION

This letter states that the following documents were translated correctly from English to isiZulu:

- Information documents
- Informed consent
- Pre-test Questionnaire
- Instructions for each test
- Case history questionnaire
- Suggestion page for pilot study
- Recruitment documents
- Pamphlet for workers
- Indemnity form for transportation



Faatima Nakhooda
Researcher

17/12/13
Date



Translator

17-12-13
Date

APPENDIX Y

DISCIPLINE OF AUDIOLOGY
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E-mail: naidoor1@ukzn.ac.za



Thank you for taking the time to read this information pamphlet. This pamphlet provides information on the research study being conducted towards my Masters degree in Audiology. The topic of my study is : “THE EFFECTS OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION- A PILOT STUDY

Kindly read the information pamphlet carefully and direct all questions to the researcher.
Thank you for your time.
Miss F. Nakhoda

INFORMATION PAMPHLET: AUDIOLOGY TESTS

Otoscopy:

Is an ear examination with an otoscope: a handheld instrument with a tiny light and a cone-shaped attachment called an ear speculum. The ear speculum, which is inserted into the ear, is cleaned and sanitized before it is used.



Figure 2 Otoscope

This examination is done to look into the ear, to see if there are any infections present or if there is impacted wax or foreign bodies in the ear canal. The patient will be asked to sit with the head tipped slightly toward the shoulder so the ear to be examined is pointing up. The Audiologist may hold the ear lobe as the tip of the otoscope is inserted into the ear. Both ears are usually examined, even if the problem seems to affect just one ear, and the procedure takes no more than a few minutes to perform.

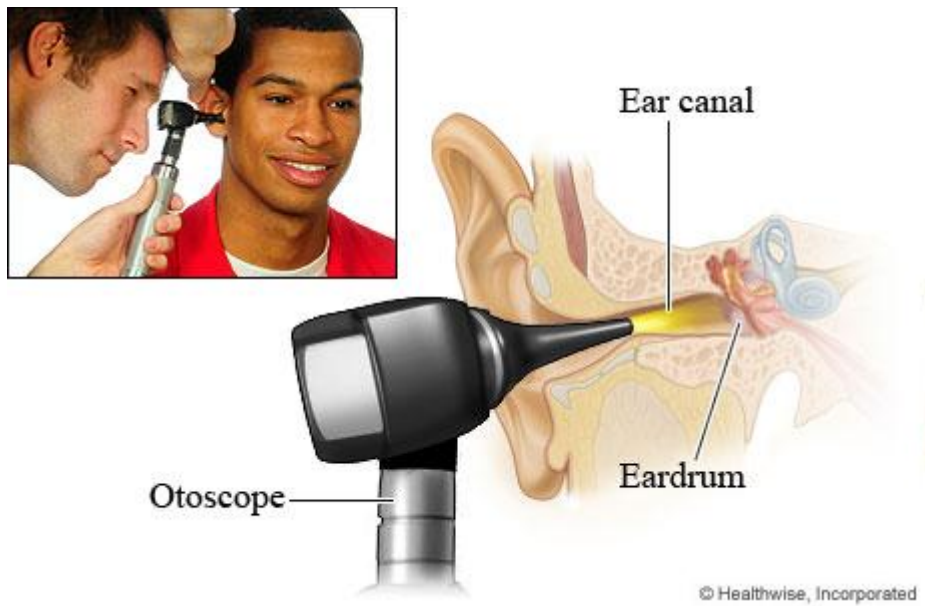


Figure 3 Audiologist conducting an otoscopic examination

Instructions for the test: I will be using a light to look into your ear. The purpose of this test is to see if everything is ok in your outer ear and your eardrum. I need you to please sit still whilst I am doing the examination. Please feel free to ask any questions.

Immittance Audiometry:

This examination is made up of 2 tests, that is; TYMPANOMETRY AND ACOUSTIC REFLEX THRESHOLD TESTING.



Figure 4 Audiologist conducting Immittance Audiometry

Tympanometry testing:

Is a test used to detect problems of the middle ear, which is where the eardrum is situated. Can be helpful in detecting fluid in the middle ear, negative middle ear pressure, problems with the middle ear bones etc. An instrument called a tympanometry machine, then measures movement of the tympanic membrane in responses to the pressure changes. A graph will be printed which will show how the eardrum response when the pressure is applied to it.



Figure 5 Immittance meter

Instructions for the test: I will be placing a sponge in your ear. When the test starts you will feel a little pressure in your ear. Please try to remain as still as possible. I will be doing the test in both ears. Avoid any unnecessary movement and excessive swallowing. If you need to cough or swallow please tell me and I will stop the test. Please feel free to ask me any questions.

Acoustic Reflex testing:

This test measures the response of a very small ear muscle that moves when there is a loud sound. Lack of this movement or the loudness at which the movement occurs provides important information about hearing loss. During the test, a series of sounds can be heard at varying levels of intensity. The sound level at which an acoustic reflex contraction occurs, or the absence of any acoustic reflex, can help the examiner evaluate hearing loss and locate problems along the auditory pathway.

Instructions for the test: I will be placing a sponge in your ear. When the test starts you will hear a tone in your ear. Please try to remain as still as possible. I will be doing this test on both ears. Avoid any unnecessary movement and excessive swallowing. If you need to cough or swallow please tell me and I will stop the test. Please feel free to ask me any questions.

Pure tone audiometry:

Hearing is measured over a range of frequencies when the tone of the sound is varied from loud to soft.

Air Conduction: Pure tone air conduction measures the ability to hear different tones of sound, measured in Hertz (Hz) and the ability to hear the loudness or intensity of these tones, measured in decibels (dB). Using this method, the audiologist begins by placing a pair of earphones over the ears. In one ear at a time, certain tones are introduced through the earphones. When a sound is heard, the patient alerts the Audiologist by pressing a button. Responses are recorded on a graph called an audiogram.



Figure 6 Audiologist conducting pure tone testing



Figure 7 Pure tone audiometer

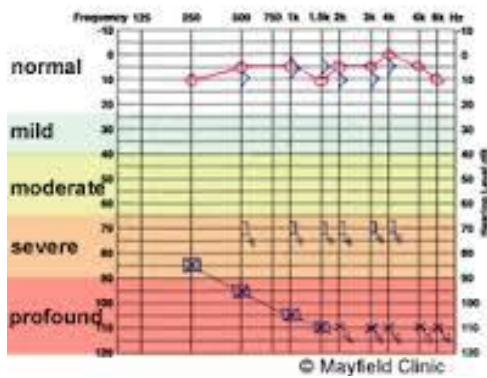


Figure 8 Audiogram

Instructions for the test: I am going to place these earphones on your ears. Through them you will hear tones. These tones sound like “beep beep”. Every time you hear the tone I want you to press the button that I’ve given you. Some of the sounds will be loud and some of them will be very soft. I need you to concentrate and when you hear the tones I want you to respond. Do you have any questions?

Bone Conduction: To check hearing by way of sounds conducted through the bones of the skull can help isolate problems in the outer and middle ear. To do this, the audiologist places a special vibrating device either behind the ear or on the forehead.



Figure 9 Audiologist conducting bone conduction testing

Instructions for testing: This test is similar to the previous test where you pressed the button when you heard the tones except that for this test I will be placing a vibrator on this bone behind the ear. I want you to please press the button every time you hear the tones through the vibrator. If you hear a wind like noise coming into the other

ear please ignore it. Only concentrate on the test ear. Do you have any questions?

Otoacoustic Emissions:

These emissions are faint sounds produced by an organ of the inner ear called the cochlea when sound stimulates it. Although people cannot hear these sounds, they can be picked up and measured by a small probe placed in the ear canal. These emissions are produced by people with normal hearing but not by those with hearing loss. This test can detect damage in the inner ear.



Figure 10 Audiologist conducting otoacoustic emission testing

Instructions for testing: I will be placing a sponge in your ear. When the test starts you will a tone in your ear. Please try to remain as still as possible. I will be doing the test on both ears. Avoid any unnecessary movement and excessive swallowing. If you need to cough or swallow please tell me and I will stop the test. Please feel free to ask me any questions.

Should you have any questions regarding any of the above information, please contact:

Faatima Nakhooda: 072 0327005 or Samantha Govender: 031 260 743

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Ngiyabonga ukuba uthathe isikhathi sakho sokufunda ulwazi olukulencwajana. Lencwajana inikezela ngolwazi mayelana nocwaningo engilwenzayo maqondana nezifundo zami zobungcwenti kwezamadlebe, Isihloko sesifundo sami sithi: **imiphumela yoketshezi oluncibilikayo nokuveza obala imisindo maqondana namadlebe kubasebenzi ngaphakathi ezimbonini**

Uyacelwa ukuba ufundise ulwazi oluqokethwe ilencwajana bese uqondisa yonke imibuzo kumcwaningi.
Siyabonga ngesikhathi sakho
Nkosazane F. Nakhoda

ULWAZI OLUQOKETHWE ILENCWAJANA: UKUHLOLELWA IZINDLEBE

OTHOSKHOPHI:

Ukuhlolwa kwengaphakathi lwendlebe ngesikhali sokusebenza esibanjwa ngesandla esinesinesibani esikhanyayo esincane esimisise okwesiyingi ngaphansi bese kuba luthumo ngaphezulu esibizwa nge sihlola madlebe. Isihlola madlebe, esifakwa ezindlebeni, siyahlanziswa ngaphambi kokuba sisetsheziwe. Lokukuhlolwa kwenzelwa ukubona ingaphakathi lezindlebe, ukubona ukuth ngabe kukhona yini ukuthleleka kwesifo ngalesosikhathi noma noma izigonogono noma isifo esingajwayelekile esingatholakala kwingaphakathi lezindlebe, isiguli sizokucelwa ukuba sihlale siketshezi ikhanda alisondeze ehlonbe ukuze indlebe ezokube ihlolwa ibheke phezulu. Udokotela wezindlebe kufanele abambe isicubu sendlebe njengesihloko se (othoskophi) isifakwe endlebeni. Zombili izindlebe kuvamise ukuba zihlolwe, noma ngabe inking ibukeka ihlasele indlebe eyodwa, futhi indlela yenqubo ayithathi isikhathi esingaphezu kwemizuzwana ukuyiqeda.

Imigomo yokuhlolwa: Ngizosebenzisa isibani ukupopola ingaphakathi lendlebe yakho. Inhloso yalokuhlolwa ukuthi sibone ukuthi ngabe yonke into imi ngendlela ikakhulukazi ingaphandle kanye nesigubhu sendlebe yakho. Ngidinga ukuba uhlale uqonde ngalesikhathi ngikuhlola. Ungakhululeka ukubuza noma imuphi umubuzo.

Immittance Audiometry

Lokuhlolwa kuhlukaniseke izigaba ezimbili, ezibizwa ngokuthi i: TYMPANOMETRY AND ACOUSTIC REFLEX THRESHOLD TESTING.

Lolu uhlobo lokuhlolwa olusetshenziswa ukuze kubonakale uma kukhona inkinga maphakathi nendawo endlebeni. Lapho isigubhu sendlebe sikhona. Ingaba usizo ekutholeni uketshezana olumaphakathi nendlebe, izinkinga mayelana nengaphakathi lamathambo endlebe nokunye nokunye. Lesikhali spkusebenza sibizwa ngokuthi 'tympanometry', lelithuluzi lokusebenza lisetshe nzelwa ukubheka umnyakazo we 'tympanic membrane' kwenzakalani kuyona uma kukhona ushintsho ekugcindazelekeni phakathi endlebeni. Kuyobe sekukhishwa igrafu eyobe iveza kabanzi ukuthi kwenzakalani kwisigubhu sendlebe uma kukhona ukugcindezeleka endlebeni

Imigomo yokuhlolwa: ngizobeka isibokoboko endlebeni yakho. Umasesiqala ukuhlolwa uyokuzwa ekugcindezeleka endlebeni. Kubalulekile ukuthi ngalesikhathi uhlale uthule unganyakazi nakancane. Lokhu kuhlolwa ngizokwenza ezindlebeni zombili. Qikelela ukuthi awunyakazi futhi awugwinyi ngokudlulileyo. Uma uzwa ufikelwa ukukhwehlela noma ufuna ukugwinya ngicela ungazise ukuze ngimise ukukuhlola ngalesosikhashana. Ungakhululeka ukuba ungibuze noma imuphi umubuzo.

Acoustic reflex testing

Lokhu kuyuhlobo lokuhlolwa lapha sihlola umsipha ongaphakathi endlebeni osivikela emisindweni emikhulu kakhulu. Ukunyakaza kwalomusipha ikona okusinika ulwazi mayelana nokuzwa noma komuntu. Uma usuxilongwa kunemisindo eminingi ezofakwa emadlebeni, uma lomusipha usunyakaza ngenxa yomusindo, ilapho esizobe sesazi ukuthi uzwa kangakanani.

Imigomo yokuhlolwa: Ngizofaka okusasipongji endlebeni yakho. Uzobe ususwa umsindo. Ngicela uzame ukunganyakazi. Ngizobe sengikuxilonga izindlebe zombili. Zama ukugwema ukugwinya kakhulu nokunyakazi. Uma udinga ukukhwehlela noma ugwinye ngicela ungazise ukuze ngimise ukukuxilonga. Ngicela ungazise uma unemibuzo.

Pure Tone Audiometry

Ukuhamba kokuzwa/umsindo ngomoya: lokhu kusuke kuxilongwa indlela okwazi ngayo ukuzwa umsindo ngama (dB). Umxilongi uqala ngokufaka izivalo madlebe ezindlebeni. Kuyake sekufakwa lemisindo endlebeni ngayinye, uma izwakala lemisindo umuntu uxilongwayo uyake acelwe ukuba acindezele ibhathini. Imiphumela ibhalwa kwipheshana elibizwa ngokuthi I Audiogram.

Imigomo yokuhlolwa: ngizofaka izivalo madlebe ezindlebeni zakho. Uzobe usuzwa imisindo ekhala ithi “beep beep”. Ngaso sonke isikhathi uma uyizwa lemisindo uyacelwa ukuba ucindezele ibhathini. Ngabe unayo imibuzo?

Bone Conduction: ukubheka ukuzwa komuntu ngokuhambisa umsindo ethanjeni elincane elitholakala ngemuva kwendlebe, lokhu kungasiza ekungabandakanyi izinkinga ekungabe unazo kwingaphandle nengaphakathi lendlebe. Ukwenza lokhu, udokotela wezindlebe ubeka into enyakazisa lelithambo ngemuva kwendlebe.

Imigomo yokuhlolwa: ngizofaka izivalo madlebe ezindlebeni zakho. Uzobe usuzwa imisindo ekhala ithi “beep beep”. Ngaso sonke isikhathi uma uyizwa lemisindo uyacelwa ukuba ucindezele ibhathini. Uma kwenzeka uzwa umsindo engathi umoya, ngicela uwugweme. Bese uqaphela lomsindo osendlebeni yakh. Ngabe unayo yini imibuzo?

Otoacoustic Emissions:

Luluhlobo lokuxilonga lubandakanya imisindo emincane etholakaya kwingaphakathi lwendlebe. Yize abantu bengakwazi ukuyizwa lemisindo koda iyakwazi ukuzwakala uma usuxilongwa. Lemisindo yengaphakathi lwendlebe lukhiqizeka uma umuntu enokuzwa okukahle kanti abanekinga yokuzwa ayitholakali kubona. Ngalokhu singakwazi ukubona uma unenkinga nengaphakathi lendlebe.

Imigomo yokuhlolwa: Ngizofaka okusasipongji endlebeni yakho. Uzobe usuzwa umsindo. Ngicela uzame ukunganyakazi. Ngizobe sengikuxilonga izindlebe zombili. Zama ukugwema ukugwinya kakhulu nokunyakaza. Uma udinga ukukhwehlela noma ugwinye ngicela ungazise ukuze ngimise ukukuxilonga. Ngicela ungazise uma unemibuzo.

Uma unemibuzo, ngicela usithinte kuleminingwane engezansi.

Faatima Nakhoda: 072 0327005 or Samantha Govender: 031 260 743

APPENDIX Z

Dip OH : BASIC PRINCIPLES OF OCCUPATIONAL HYGIENE – 3rd to 7th March 2014

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
8.30 – 9.30	Intro to occupational hygiene - JH	Assessment of Health Risks - JH	General approaches to the Control of Risk to Health - JH	Lighting and non- ionising radiation – JH Ionising radiation - JH	Introduction to stress and its management – JH
9.30 – 10.30	Occupational hygiene Standards and Occupational Exposure Limits - JH		Ventilation - JH	Introduction to noise – SC	Introduction to Careers in Occupational Hygiene - JH
10.30 - 11.00	TEA				
11.00 - 12.30	Human Physiology - RN	Assessment of health Risks - JH	Biological Hazards – SN	Introduction to Vibration – SC & JH	Biological Monitoring and health surveillance – SN
12.30 - 13.15	LUNCH				
13.15 – 14.15	Fundamentals of toxicology - JH	Assessment of health Risks - JH	Asbestos - JH	Introduction to Ergonomics & Display screen equipment - SC	Exam prep
14.15 - 14.45	TEA				
14.45 – 15.45	Examples of Hazardous Substance Processes - JH	Measurement of Hazardous Chemicals - JH	Human factors & behavioural safety - GH	Introduction to Thermal Environment - JH	14.00 – 15.00 Exam OHTA students
15.45 – 16.45					

Lecturers:

RN = Rajen Naidoo, SC = Sean Chester, GH = Garth Hunter, SN = Saloshni Naidoo, JH = Julie Hills

APPENDIX AA

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To: Julie Hills (Occupational Hygienist)

Re: Request for permission to use department equipment

I would first like to take this opportunity to thank you for your assistance thus far. I am an Audiology master's student at UKZN Westville Campus currently conducting research at factories across Durban. My topic is "THE EFFECT OF OCCUPATIONAL EXPOSURE TO CHEMICAL SOLVENTS ON AUDITORY FUNCTION".

In order to conduct my study, I will need the following equipment:

- Personal Air Sampling pumps
- Low flow sampling heads
- Activated Charcoal sorbent tubes
- A primary calibrator to check flow rates

I am asking permission to utilize this equipment for a period of 2 weeks under your supervision (Julie Hills). I will access the equipment via you (Julie Hills) and will utilize the equipment with utmost care as well as sign any documentation regarding indemnity/care of equipment.

Below is a section for you to sign, so that I have written consent.

Thank you for your time, it is appreciated.

Should you have any queries, please contact me on 0720327005 or my supervisor Mrs. S. Govender on 0734990703.

Thank you
Yours sincerely



Faatima Nakhooda (researcher)

Permission for the above requested granted by: J Hills - DOEH-UKZN

Signature: 

Date: 16/4/2014

APPENDIX BB

Participant particulars

STUDY	PARTICIPANTS	HUMAN/ ANIMAL	OCCUPATIONAL SETTING	COUNTRY	EXPOSURE LEVELS
Ikuharu, Nobuyuki, Hiroichi, & Kazuhisa, 2000	- 54 male workers - 20-68 years old - Divided into 3 groups, combined group (23), noise group (19), control group (12)	Human	Plastic buttons industry	Japan	Noise: Within OEL's Solvents: Within OEL's
Kim, Park, HA, Jung, Paik, & Yang, 2005	- 328 male workers - Exposure to noise (146), solvents (18), noise and solvents (13), none (151)	Human	Avionics	Korea	Noise: Above OEL's Solvents: Above OEL's
Prasher, Al-Hajjal, Aylott, & Aksentijevic, 2005	- 4 groups - Noise only, solvents only, noise and solvents, none	Human	Aircraft maintenance	-	-
Chang, Chen, Lien, & Sung, 2006	- 174 workers - 58 workers exposed to toluene and noise- 58 workers exposed to noise- 58 admin clerks	Human	Adhesive materials manufacturing plant	Taiwan	Noise: Above OEL's Solvents: Above OEL's
Schaper, Seeber, & Van Thriel, 2008	- 333 male workers	Human	Printing industry	Germany	Noise: Above OEL's Solvents: Above OEL's
Botelho, Paz, Gonçalves, & Frota, 2009	- 155 workers - Exposed to noise only (81) and also noise and chemicals (71) - Age 18-50 years - Working for 3-20 years.	Human	Metallurgical workers	Rio de Janeiro	-
Mohammadi, Labbafinejad, & Attarchi, 2010	- Worked for more than 6 months - All male - 164 in old paint shop (noise and mixed solvents at high concentration levels). - 104 new (noise and mixed solvents at low concentration levels). - 173 assembly shop (noise only).	Human	Car manufacturing	Iran	Noise: Above OEL's Solvents: Above OEL's
Barba, Jurkiewicz, Zeigelboim, de Oliveira, & Belle, 2005	- 2 groups: group 1 (solvents and noise) and group 2 (noise).	Human	Petrochemicals	Brazil	-

Lobato, De Lacerda, Gonçalves, & Coifman, 2014	<ul style="list-style-type: none"> - 198 workers - 4 groups: noise group, exposed only to noise; the noise and solvents group, exposed to noise and solvents; the noise control group and noise and solvents control group, no exposure. 	Human	Metal graphics	Brazil	-
Hughes & Hunting, 2013	<ul style="list-style-type: none"> - 4 exposure profiles: Noise with solvents, noise alone, solvents alone and neither noise nor solvents. - 503 workers from two Air Force Reserve sites. - 41 subjects did not meet the study inclusion criteria. 	Human	Aviation industry	USA	Noise: Above OEL's Solvents: Below OEL's
Rizk & Sharaf, 2010	<ul style="list-style-type: none"> - 110 workers in a fermentation plant divided into two groups. - Group A (50 workers,) exposed to noise only, group B (60 workers) exposed to noise and mixture of organic solvents, - Control group (group C; 30 workers) were neither exposed to noise nor organic solvents. 	Human	Fermentation plant	Egypt	-
Chang, Shih, Chou, Chen, Chang, & Sung, 2003	<ul style="list-style-type: none"> - 131 men with exposure to noise and CS₂ in a viscose rayon plant. - 105 men in the adhesive tape and electronic industries who were exposed to noise only - 110 men employed in the administrative office of the rayon plant who were exposed to low noise and no CS₂. 	Human	Viscose rayon manufacturing	Taiwan	Noise: Above OEL's Solvents: Above OEL's
Metwally, Aziz, Mahdy- Abdallah, Said AbdelGelil, & El-Tahlawy, 2012	<ul style="list-style-type: none"> - 3 groups. - 70 workers exposed to noise only, the second group consisted of 93 workers exposed to organic solvents and noise, and the control group included 59 individuals exposed to neither noise nor organic solvents. 	Human	Painting production	Egypt	Noise: Within OEL's Solvents: Below OEL's

APPENDIX DD

No.	YEAR	COUNTRY	ARTICLE	EXPOSURE	OBJECTIVE	METHOD	RESULTS	CONCLUSION	REFERENC ES
1	2000	Japan	Evaluation of combined effect of organic solvents and noise by the upper limit of hearing	Organic Solvents and Noise	To clarify the combined effect of organic solvents and noise on the upper limit of hearing in workers occupationally exposed to both organic solvents and noise at relatively low levels.	54 male workers between 20-68 years. Divided into 3 groups, 23 combine group, 19 noise group, 12 control group. Upper limit of hearing was tested (500Hz to 50KHz) and air conduction testing done.	Noise levels and solvent levels were within occupational exposure limits. No significant correlation was found between upper limit of hearing and pure tones and organic solvent concentrations in the working environment Reduction of upper limit of hearing was largest in combine group, thus there could be a probable combined effect on hearing even when levels are within limits.	A probable combined effect of solvents and noise on hearing even when levels were relatively low	Ikuharu, Nobuyuki, Hiroichi, & Kazuhisa, 2000
2	2005	Korea	Combined effects of noise and mixed solvents exposure on the hearing function among workers in the aviation industry	Noise and Mixed Solvents	To evaluate the effects of occupational lifetime exposure to noise and organic solvents on hearing loss in the aviation industry	328 male workers from avionics jobs. Solvents included methyl ethyl ketone, toluene, xylene and methyl isobutyl ketone. Exposure to Noise (146), solvents (18), noise and solvents (13), none (151). Pure-tone audiometry was used. 14 hour rest period before testing.	Prevalence of hearing loss in noise and solvent group was higher than other groups (54.9%).	Chronic exposure to mixed solvents had a toxic effect on the auditory system.	Kim, Park, HA, Jung, Paik, & Yang, 2005
3	2005	-	Effect of exposure to a mixture of solvents and noise on hearing and balance in aircraft maintenance workers	Solvents and Noise	To evaluate the effects of solvents and noise on hearing and balance in workers.	4 groups were tested- noise only, solvents only, noise and solvents, none. Pure Tone, OAEs, ABR, VNG and Posturography were done.	There was a significant effect on pure-tone audiometry thresholds for noise and for noise and solvent groups. OAEs declined with frequency and showed lower DP amplitude with noise compared to noise and solvent group. 32% of workers had abnormalities of ABR who were exposed to noise and solvents. 32% of workers in solvents and noise group had abnormal posturography results. Workers had abnormal results for VNG results in	The effects of a mixture of solvents on the auditory system appears to occur both at the end organ level as well as in the nervous pathway.	Prasher, Al-Hajjal, Aylott, & Aksentijevic, 2005

							noise and solvent group.		
4	2006	Taiwan	Hearing loss in workers exposed to toluene and noise	Toluene and Noise	To evaluate long term effects of combined exposure to toluene and noise on audiometric thresholds	Cross sectional design- 1 study group and 2 reference groups. 174 workers at an adhesive materials manufacturing plant. 58 workers exposed to toluene and noise- 58 workers exposed to noise- 58 admin clerks. Used Pure Tone testing.	Higher prevalence of hearing loss in toluene and noise group. Hearing impairment higher at 1KHz than 2KHz. Mean hearing threshold lowest at 6KHz and least effect observed at 2KHz.	Toluene exacerbates hearing loss in a noisy environment, with the main impact at lower frequencies	Chang, Chen, Lien, & Sung, 2006
5	2008	Germany	The effects of toluene plus noise on hearing thresholds: an evaluation based on repeated measurements in the German printing industry	Toluene and Noise	The ototoxicity of occupational exposure to toluene and noise was investigated in a longitudinal study in rotogravure printing and existing findings in the literature was evaluated	4 repeated measures over 5 years were done, 333 male workers. Pure-tone audiometry was done.	The threshold for developing hearing loss as a result of occupational exposure to toluene plus noise was above the current limit of 50ppm.	Due to missing toluene effects, the conclusion is that the threshold for developing hearing loss as a result of occupational exposure to toluene plus noise might be above the current limit of 50ppm.	Schaper, Seeber, & Van Thriel, 2008
6	2009	Rio de Janeiro	Comparative study of audiometric tests on metallurgical workers exposed to noise only as well as noise associated to the handling of chemical products	Noise and Chemicals	To perform a comparative study through audiometric tests in workers exposed to noise only and noise associated with chemical products	155 workers exposed to noise only 81 (group 1) and also noise and chemicals 71 (group 2). Age 18-50 years. 14 hour rest period before testing. AC, BC, SRT, SRS was done. Working for a period of 3-20 years.	Greater hearing loss in group 2 (18.3%) than group 1 (6%). Chemicals found were styrene, resins and cobalt.	Group 2 had a proportionally higher hearing loss than group 1.	Botelho, Paz, Gonçalves, & Frota, 2009
7	2010	Iran	Combined effects of ototoxic solvents and noise on hearing in automobile plant workers in Iran	Organic Solvents and Noise	To evaluate the effects of occupational exposure to noise and mixed organic solvents on hearing loss in car manufacture	Cross sectional design. Automobile plant. All workers who worked for more than 6 months. All male. 164 in old paint shop (noise and mixed solvents at high concentration levels). 104 new (noise and mixed solvents at low concentration levels). 173 assembly shop (noise only). Pure-tone	Solvents found were xylene, toluene, benzene, tetrachloroethylene and acetone. High frequency hearing loss was more common in workers exposed to noise and mixed solvents.	Combined exposure to mixed solvents and noise can exacerbate hearing loss.	Mohammadi, Labbafinejad, & Attarchi, 2010

					workers	audiometry was done.			
8	2005	Brazil	Audiometric findings in petrochemical workers exposed to noise and chemical agents	Mixed solvents	To investigate the occurrence of hearing loss among workers of a petrochemical industry during a period of five years.	The records of environmental noise and solvents measurements and the results of annual audiometry performed by the company were examined. 2 groups: group 1 were workers exposed to solvents and noise and group 2 were workers exposed only to noise.	Despite the low exposures to solvents and a moderate exposure to noise, 45.3% of workers had hearing losses and 29.6% had threshold shifts.	This study suggests the necessity for reviewing the preventive measurements adopted by the company studied for eliminating the occurrence of hearing losses and standard threshold shift.	Barba, Jurkiewicz, Zeigelboim, de Oliveira, & Belle, 2005
9	2014	Brazil	Auditory Effects of Exposure to Noise and Solvents: A Comparative Study	Solvents	To evaluate the effects of the combined exposure to noise and solvents on hearing in workers.	A transversal retrospective cohort study was performed. The sample (198) was divided into four groups: the noise group, exposed only to noise; the noise and solvents group, exposed to noise and solvents; the noise control group and noise and solvents control group, no exposure.	The noise group and noise and solvent group had worse thresholds than their respective control groups. Females were less susceptible to noise than males; however, when simultaneously exposed to solvents, hearing was affected in a similar way. The 40- to 49-year-old age group was significantly worse in the auditory thresholds.	The results observed in this study indicate that simultaneous exposure to noise and solvents can damage the peripheral auditory system.	Lobato, De Lacerda, Gonçalves, & Coifman, 2014
10	2013	USA	Evaluation of the effects of exposure to organic solvents and hazardous noise among US Air Force Reserve personnel	Organic solvents	To evaluate the risk for hearing loss among Air Force Reserve personnel exposed to occupational noise with and without exposures to toluene, styrene, xylene, benzene, and JP-8 (jet fuel).	Data were collected retrospectively from existing audiometric examinations, industrial hygiene documentation. Four general exposure profiles were sought: Noise with solvents, noise alone, solvents alone and neither noise nor solvents. Workplaces jobs included aircraft maintenance, flight line operations, air operations (aircrew), plumbing, electrical, carpentry, painting, heating ventilation and air conditioning, warehouse operations, vehicle maintenance, security and fire fighting. The study population consisted of 503 workers from two Air Force Reserve sites. 41 subjects	Followed for an average of 3.2 years, 9.2% of the study subjects had hearing loss in at least one ear. Increasing age and each year of follow-up time were significantly associated with hearing loss. Low and moderate solvent exposures were not associated with hearing loss.	Workers who are exposed to increasing levels of noise gradually lose hearing sensitivity over time.	Hughes & Hunting, 2013

						did not meet the study inclusion criteria.			
11	2010	Egypt	Health hazards among a sample of workers exposed to a combination of noise and organic solvents in a fermentation factory in Egypt	Organic solvents	To study the risk of hearing loss among a sample of fermentation plant workers exposed to both noise and a mixture of organic solvents.	The exposed group consisted of 110 workers in a fermentation plant divided into two groups. Group A (50 workers,) exposed to noise only, group B (60 workers) exposed to noise and mixture of organic solvents, The control group (group C; 30 workers) were neither exposed to noise nor organic solvents. All studied sample were subjected to complete medical examination and audiometric examination using pure tone Audiometer.	Noise level was comparable in groups A&B but significantly higher than in control work places. Thirty six percent of exposed workers suffered from hearing loss versus 3.3 percent in the control group. Hearing loss was significantly higher among group B (24%) than group A (18%). Results showed that both exposed groups had higher hearing loss than normal control.	Workers exposed to both noise and organic solvents suffered from the highest proportion of hearing loss compared to those exposed to noise alone.	Rizk&Sharaf, 2010
12	2003	Taiwan	Hearing Loss in Workers Exposed to Carbon Disulfide and Noise	Carbon disulphide	To investigate hearing loss for workers exposed simultaneously to carbon disulphide (CS ₂) and noise, compared with workers with noise exposure only and workers with low noise and no CS ₂ exposure.	131 men with exposure to noise and CS ₂ in a viscose rayon plant. These men were compared with 105 men in the adhesive tape and electronic industries who were exposed to noise only and with 110 men employed in the administrative office of the rayon plant who were exposed to low noise and no CS ₂ .	Results showed a prevalence of hearing loss of > 25 dB hearing loss in rayon workers (67.9%) was much higher than that in administrative workers (23.6%) and in the adhesive tape and electronic industrial workers (32.4%). Hearing loss occurred mainly for speech frequencies of 0.5, 1, and 2 kHz.	The study suggests that CS ₂ exposure enhances human hearing loss in a noisy environment and mainly affects hearing in lower frequencies.	Chang, Shih, Chou, Chen, Chang, & Sung, 2003
13	2012	Egypt	Effect of combined occupational exposure to noise and organic solvents on hearing	Mixture of organic solvents	To evaluate the hearing of workers exposed to both noise and a mixture of organic solvents at concentrations anticipated as safe.	The study comprised of three groups. The first one included 70 workers exposed to noise only, the second group consisted of 93 workers exposed to organic solvents and noise, and the control group included 59 individuals exposed to neither noise nor organic solvents. Questionnaires were given to workers; Otoscopic examinations were conducted as well	No statistically significant difference between the two exposed groups as regards the duration of exposure. There was a highly statistically significant difference between the two exposed groups as regards the different types of hearing. The difference between the two groups was statistically significant regarding this type of hearing impairment. There was a positive significant correlation between hearing	It is recommended that in the case of combined exposure, noise and solvent levels should be lowered than the permissible limits recommended for either alone.	Metwally, Aziz, Mahdy-Abdallah, Said AbdElGeli, & El-Tahlawy, 2012

						as pure tone audiometry.	impairment and duration of exposure in the two exposed groups.		
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Abbreviations used: DP (Distortion Product)- SRS (Speech Recognition Score)- VNG (Videonystagmography)- ppm (parts per million)- USA (United States of America)- AC (Air Conduction)- BC (bone Conduction)- SRT (speech Reception Testing)- OAEs (Oto acoustic Emissions)- ABR (Auditory Brainstem Response)

APPENDIX EE

CHARACTERISTICS OF STUDIES

CHARACTERISTICS OF INCLUDED STUDIES

ARTICLE: Evaluation of combined effect of organic solvents and noise by the upper limit of hearing	
AUTHOR: Ikuharu, Nobuyuki, Hiroichi, & Kazuhisa, 2000	
METHODS	Upper limit of hearing was tested (500Hz to 50KHz). Air conduction testing done.
PARTICIPANTS	54 male workers between 20-68 years. Divided into 3 groups, 23 combined group, 19 noise group, 12 control group.
RESULTS	Noise levels and solvent levels were within occupational exposure limits. No significant correlation was found between upper limit of hearing and pure tones and organic solvent concentrations in the working environment. Reduction of upper limit of hearing was largest in combined group, thus there could be a probable combined effect on hearing even when levels are within limits.
OUTCOMES	A probable combined effect of solvents and noise on hearing even when levels were relatively low.

ARTICLE: Combined effects of noise and mixed solvents exposure on the hearing function among workers in the aviation industry	
AUTHOR: Kim, Park, HA, Jung, Paik, & Yang, 2005	
METHODS	Solvents included methyl ethyl ketone, toluene, xylene and methyl isobutyl ketone. PURE-TONE AUDIOMETRY was used. 14 hour rest period before testing.
PARTICIPANTS	328 male workers from avionics jobs. Exposure to noise (146), solvents (18), noise and solvents (13), none (151).
RESULTS	Prevalence of hearing loss in noise and solvent group was higher than other groups (54.9%).
OUTCOMES	Chronic exposure to mixed solvents had a toxic effect on the auditory system.

ARTICLE: Effect of exposure to a mixture of solvents and noise on hearing and balance in aircraft maintenance workers	
AUTHOR: Prasher, Al-Hajjal, Aylott, & Aksentijevic, 2005	
METHODS	PT, OAEs, ABR, VNG and Posturography were done.
PARTICIPANTS	4 groups were tested- noise only, solvents only, noise and solvents, none.
RESULTS	There was a significant effect on PURE-TONE AUDIOMETRY thresholds for noise and for noise and solvent groups. OAEs declined with frequency and showed lower DP amplitude with noise compared to noise and solvent group. 32% of workers had abnormalities of ABR who were exposed to noise and solvents. 32% of workers in solvents and noise group had abnormal posturography results. Workers had abnormal results for VNG results in noise and solvent group.
OUTCOMES	The effects of a mixture of solvents on the auditory system appears to occur both at the end organ level as well as in the nervous pathway.

ARTICLE: Hearing loss in workers exposed to toluene and noise	
AUTHOR: Chang, Chen, Lien, & Sung, 2006	

METHODS	Cross sectional design- 1 study group and 2 reference groups. Used PT testing.
PARTICIPANTS	174 workers at an adhesive materials manufacturing plant. 58 workers exposed to toluene and noise- 58 workers exposed to noise- 58 admin clerks.
RESULTS	Higher prevalence of hearing loss in toluene and noise group. Hearing impairment higher at 1KHz than 2KHz. Mean hearing threshold lowest at 6KHz and least effect observed at 2KHz.
OUTCOMES	Toluene exacerbates hearing loss in a noisy environment, with the main impact at lower frequencies

ARTICLE: The effects of toluene plus noise on hearing thresholds: an evaluation based on repeated	
AUTHOR: Schaper, Seeber, & Van Thriel, 2008	
METHODS	4 repeated measures over 5 years were done. PURE-TONE AUDIOMETRY was done.
PARTICIPANTS	333 male workers
RESULTS	The threshold for developing hearing loss as a result of occupational exposure to toluene plus noise was above the current limit of 50ppm.
OUTCOMES	Due to missing toluene effects, the conclusion is that the threshold for developing hearing loss as a result of occupational exposure to toluene plus noise might be above the current limit of 50ppm.

ARTICLE: Comparative study of audiometric tests on metallurgical workers exposed to noise only as well as noise associated to the handling of chemical products	
AUTHOR: Botelho, Paz, Gonçalves, & Frota, 2009	
METHODS	14 hour rest period before testing. AC, BC, SRT, SRS was done.
PARTICIPANTS	155 workers exposed to noise only 81 (group 1) and also noise and chemicals 71 (group 2). Age 18-50 years. Working for a period of 3-20 years.
RESULTS	Greater hearing loss in group 2 (18.3%) than group 1 (6%). Chemicals found were styrene, resins and cobalt.
OUTCOMES	Group 2 had a proportionally higher hearing loss than group 1.

ARTICLE: Combined effects of ototoxic solvents and noise on hearing in automobile plant workers in Iran	
AUTHOR: Mohammadi, Labbafinejad, & Attarchi, 2010	
METHODS	Cross sectional design. Automobile plant. PURE-TONE AUDIOMETRY was done.
PARTICIPANTS	All workers who worked for more than 6 months. All male. 164 in old paint shop (noise and mixed solvents at high concentration levels). 104 new (noise and mixed solvents at low concentration levels). 173 assembly shop (noise only).
RESULTS	Solvents found were xylene, toluene, benzene, tetrachloroethylene and acetone. High frequency hearing loss was more common in workers exposed to noise and mixed solvents.
OUTCOMES	Combined exposure to mixed solvents and noise can exacerbate hearing loss.

ARTICLE: Audiometric findings in petrochemical workers exposed to noise and chemical agents	
AUTHOR: Barba, Jurkiewicz, Zeigelboim, de Oliveira, & Belle, 2005	
METHODS	The records of environmental noise and solvents measurements and the results of annual audiometry performed by the company were examined.
PARTICIPANTS	2 groups: group 1 (solvents and noise) and group 2 (noise).
RESULTS	Despite the low exposures to solvents and a moderate exposure to noise, 45.3% of workers had hearing losses and 29.6% had threshold shifts.
OUTCOMES	This study suggests the necessity for reviewing the preventive measurements adopted by the company studied for eliminating the occurrence of hearing losses and standard threshold shift.

ARTICLE: Auditory Effects of Exposure to Noise and Solvents: A Comparative Study	
AUTHOR: Lobato, De Lacerda, Gonçalves, &Coifman, 2014	
METHODS	A transversal retrospective cohort study was performed
PARTICIPANTS	198 workers 4 groups: noise group, exposed only to noise; the noise and solvents group, exposed to noise and solvents; the noise control group and noise and solvents control group, no exposure.
RESULTS	The noise group and noise and solvent group had worse thresholds than their respective control groups. Females were less susceptible to noise than males; however, when simultaneously exposed to solvents, hearing was affected in a similar way. The 40- to 49-year-old age group was significantly worse in the auditory thresholds.
OUTCOMES	The results observed in this study indicate that simultaneous exposure to noise and solvents can damage the peripheral auditory system.

ARTICLE: Evaluation of the effects of exposure to organic solvents and hazardous noise among US Air Force Reserve personnel	
AUTHOR: Hughes & Hunting, 2013	
METHODS	Data were collected retrospectively from existing audiometric examinations, industrial hygiene documentation
PARTICIPANTS	4 exposure profiles: Noise with solvents, noise alone, solvents alone and neither noise nor solvents. 503 workers from two Air Force Reserve sites. 41 subjects did not meet the study inclusion criteria.
RESULTS	Followed for an average of 3.2 years, 9.2% of the study subjects had hearing loss in at least one ear. Increasing age and each year of follow-up time were significantly associated with hearing loss. Low and moderate solvent exposures were not associated with hearing loss.
OUTCOMES	Workers who are exposed to increasing levels of noise gradually lose hearing sensitivity over time.

ARTICLE: Health hazards among a sample of workers exposed to a combination of noise and organic solvents in a fermentation factory in Egypt	
AUTHOR: Rizk&Sharaf, 2010	
METHODS	All studied sample were subjected to complete medical examination and audiometric examination using pure tone Audiometer.
PARTICIPANTS	110 workers in a fermentation plant divided into two groups. Group A (50 workers,) exposed to noise only, group B (60 workers) exposed to noise and mixture of organic solvents, Control group (group C; 30 workers) were neither exposed to noise nor organic solvents.

RESULTS	Noise level was comparable in groups A&B but significantly higher than in control work places. Thirty six percent of exposed workers suffered from hearing loss versus 3.3 percent in the control group. Hearing loss was significantly higher among group B (24%) than group A (18%). Results showed that both exposed groups had higher hearing loss than normal control.
OUTCOMES	Workers exposed to both noise and organic solvents suffered from the highest proportion of hearing loss compared to those exposed to noise alone.

ARTICLE: Hearing Loss in Workers Exposed to Carbon Disulfide and Noise	
AUTHOR: Chang, Shih, Chou, Chen, Chang, & Sung, 2003	
METHODS	-
PARTICIPANTS	131 men with exposure to noise and CS ₂ in a viscose rayon plant. 105 men in the adhesive tape and electronic industries who were exposed to noise only 110 men employed in the administrative office of the rayon plant who were exposed to low noise and no CS ₂ .
RESULTS	Results showed a prevalence of hearing loss of > 25 dB hearing loss in rayon workers (67.9%) was much higher than that in administrative workers (23.6%) and in the adhesive tape and electronic industrial workers (32.4%). Hearing loss occurred mainly for speech frequencies of 0.5, 1, and 2 kHz.
OUTCOMES	The study suggests that CS ₂ exposure enhances human hearing loss in a noisy environment and mainly affects hearing in lower frequencies.

ARTICLE: Effect of combined occupational exposure to noise and organic solvents on hearing	
AUTHOR: Metwally, Aziz, Mahdy-Abdallah, Said AbdelGelil, & El-Tahlawy, 2012	
METHODS	Questionnaires were given to workers; Otoscopic examinations were conducted as well as pure tone audiometry.
PARTICIPANTS	3 groups 70 workers exposed to noise only, the second group consisted of 93 workers exposed to organic solvents and noise, and the control group included 59 individuals exposed to neither noise nor organic solvents.
RESULTS	No statistically significant difference between the two exposed groups as regards the duration of exposure. There was a highly statistically significant difference between the two exposed groups as regards the different types of hearing. The difference between the two groups was statistically significant regarding this type of hearing impairment. There was a positive significant correlation between hearing impairment and duration of exposure in the two exposed groups.
OUTCOMES	It is recommended that in the case of combined exposure, noise and solvent levels should be lowered than the permissible limits recommended for either alone.

CHARACTERISTICS OF EXCLUDED STUDIES

ARTICLE: Auditory neuropathy in a patient exposed to xylene: case report	
AUTHOR: Draper & Bamiou, 2009	
METHODS	-
PARTICIPANTS	1 adult
RESULTS	The patient presented with a gradual deterioration in his ability to hear in difficult acoustic environments and also to hear complex sounds such as music, over a 40-year period. His symptoms began following exposure to the solvent xylene, and in the absence of any other risk factor. Audiological investigations revealed normal OAEs with absent ABR and absent acoustic

	reflexes in both ears, consistent with a diagnosis of bilateral auditory neuropathy. Central test results were also abnormal, indicating possible involvement of the central auditory pathway.
OUTCOMES	This is the first report of retrocochlear hearing loss following xylene exposure. The test results may provide some insight into the effect of xylene as an isolated agent on the human auditory pathway.

ARTICLE: Audiological findings in individuals exposed to organic solvents: case studies	
AUTHOR: Gopal, 2008	
METHODS	A battery of audiological tests was administered to all subjects: PURE-TONE AUDIOMETRY, speech, and impedance audiometry, OAEs, ABR, MLR, as well as the SCAN-A and R-SPIN tests with low predictability sentence lists.
PARTICIPANTS	7 adults- exposed to toluene, xylene, styrene. Exposed at least 3 years.
RESULTS	All individuals in this study exhibited findings consistent with retrocochlearand/or central abnormality. Two of the seven subjects in this study had normal pure tone thresholds at all frequencies bilaterally, yet showed abnormal retrocochlear/central results on one or more tests.
OUTCOMES	The auditory test battery approach used in this study appears to be valuable in evaluating the pathological conditions of the CANS in solvent-exposed individuals.

ARTICLE: Styrene Induced Alterations in Biomarkers of Exposure and Effects in the Cochlea: Mechanisms of Hearing Loss	
AUTHOR: Chen, Chi, Kostyniak, & Henderson, 2007	
METHODS	In this study, rats were exposed to styrene at different doses once a day for varying periods.
PARTICIPANTS	Long Evans pigmented rats (male, 330 ± 32 g) were used
RESULTS	Styrene levels in the cochlear tissues, styrene induced permanent hearing loss, cochlear disruptions, and cell death pathways were determined. After 3 weeks of exposure (5 days per week), a dose-dependent permanent hearing loss and a hair cell loss, especially in the mid frequency region, were observed. Deiters cells appeared to be the most vulnerable target of styrene.
OUTCOMES	Apoptotic cell death appeared to be the main cell death pathway in the cochlea after styrene exposure. In the styrene-induced apoptotic OHCs, histo chemical staining detected activated caspases-9 and 8, indicating that both mitochondrial dependent pathway and death receptor-dependent pathway were involved in the styrene-induced cell death.

ARTICLE: Potentiation of noise induced threshold shifts and hair cell loss by carbon monoxide	
AUTHOR: Fechter, Young, & Carlisle, 1988	
METHODS	Rats received acute exposure to carbon monoxide, noise, or both agents concurrently. Thresholds were evaluated 2-4 and 6-8 weeks later.
PARTICIPANTS	Subjects were 16 male Long-Evans hooded rats, weighing between 300 and 350 g at the start of testing.
RESULTS	The data showed that carbon monoxide alone does not affect either auditory thresholds or compromise hair cells at the light microscopic level. The noise exposure alone produced variable, but quite limited permanent threshold shifts which were related to the power spectrum of the broad band noise that was employed. Hair cell loss was restricted to the basal turn of the cochlea. Simultaneous exposure to carbon monoxide and noise induced large threshold shifts at all

	<p>frequencies studied, but the effect was greatest at the highest test frequency; an effect not consistent with the noise power spectrum.</p> <p>Widespread hair cell loss persisted over fully half of the basilar membrane in the most severely affected rat.</p> <p>Outer hair cells appear to be particularly vulnerable.</p> <p>Carbon monoxide plus noise did not appear to preferentially disrupt a particular row of outer hair cells.</p>
OUTCOMES	<p>These data complement existing evidence that hyperoxia can mitigate against noise induced injury and reinforce the view that some types of noise induced damage may result from metabolic insufficiencies.</p>

ARTICLE: Ototoxicity of Toluene in Rats	
AUTHOR: Sullivan, Rarey, & Conolly, 1989	
METHODS	BAER thresholds were recorded from four toluene-treated and four control rats prior to dosing (main experiment) and from all rats after dosing (both experiments).
PARTICIPANTS	In the preliminary experiment, 5 male Sprague-Dawley rats were used. In the main experiment, eight male Sprague-Dawley rats were used.
RESULTS	<p>Loss of outer hair cells occurred in all toluene-treated rats in the middle and basal turns of the organ of Corti, with the greatest loss in the third row and progressively less in the second and first rows.</p> <p>This loss was more severe in toluene-treated rats that demonstrated elevated BAER thresholds in midfrequency regions, typically 2-8 kHz.</p>
OUTCOMES	<p>These experiments demonstrate that auditory changes are associated with cochlear hair cell loss in toluene-treated rats.</p> <p>These ototoxic effects of toluene contrast with those of other known ototoxicants, e.g., aminoglycoside antibiotics, in terms of the position of hair cell lesion in the organ of Corti and in the pattern of hair cell loss.</p>

APPENDIX FF



9 June 2015

Mrs Faatima Nakhooa 208502321
School of Health Sciences-Audiology
Westville Campus

Dear Mrs Nakhooa

Protocol reference number: HSS/0637/015M

Project title: The effects of combined exposure of solvents and noise on auditory function-a systematic review

Full Approval – No Risk / Exempt Application

In response to your application received on 3 June 2015, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted FULL APPROVAL.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

Dr Shamila Naidoo (Deputy Chair)
Humanities & Social Sciences Ethics Committee

/pm

Cc Supervisor: Mrs Samantha Govender
Cc Academic Leader Research: Professor Johan Van Heerden
Cc School Administrator: Ms P Nene

Humanities & Social Sciences Research Ethics Committee

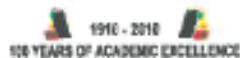
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APPENDIX GG

Participant particulars

STUDY	PARTICIPANTS	HUMAN/ ANIMAL	OCCUPATIONAL SETTING	COUNTR Y	EXPOSURE LEVELS
Ikuharu, Nobuyuki, Hiroichi, & Kazuhisa, 2000	<ul style="list-style-type: none"> - 54 male workers - 20-68 years old - Divided into 3 groups, combined group (23), noise group (19), control group (12) 	Human	Plastic buttons industry	Japan	Noise: Within OEL's Solvents: Within OEL's
Kim, Park, HA, Jung, Paik, & Yang, 2005	<ul style="list-style-type: none"> - 328 male workers - Exposure to noise (146), solvents (18), noise and solvents (13), none (151) 	Human	Avionics	Korea	Noise: Above OEL's Solvents: Above OEL's
Prasher, Al-Hajjal, Aylott, & Aksentijevic, 2005	<ul style="list-style-type: none"> - 4 groups - Noise only, solvents only, noise and solvents, none 	Human	Aircraft maintenance	-	-
Chang, Chen, Lien, & Sung, 2006	<ul style="list-style-type: none"> - 174 workers - 58 workers exposed to toluene and noise- 58 workers exposed to noise- 58 admin clerks 	Human	Adhesive materials manufacturing plant	Taiwan	Noise: Above OEL's Solvents: Above OEL's
Schaper, Seeber, & Van Thriel, 2008	<ul style="list-style-type: none"> - 333 male workers 	Human	Printing industry	Germany	Noise: Above OEL's Solvents: Above OEL's
Botelho, Paz, Gonçalves, & Frota, 2009	<ul style="list-style-type: none"> - 155 workers - Exposed to noise only (81) and also noise and chemicals (71) - Age 18-50 years - Working for 3-20 years. 	Human	Metallurgical workers	Rio de Janeiro	-
Mohammadi, Labbafinejad, & Attarchi, 2010	<ul style="list-style-type: none"> - Worked for more than 6 months - All male - 164 in old paint shop (noise and mixed solvents at high concentration levels). - 104 new (noise and mixed solvents at low concentration levels). - 173 assembly shop (noise only). 	Human	Car manufacturing	Iran	Noise: Above OEL's Solvents: Above OEL's
Barba, Jurkiewicz, Zeigelboim, de Oliveira, & Belle, 2005	<ul style="list-style-type: none"> - 2 groups: group 1 (solvents and noise) and group 2 (noise). 	Human	Petrochemicals	Brazil	-
Lobato, De Lacerda, Gonçalves, & Coifman, 2014	<ul style="list-style-type: none"> - 198 workers - 4 groups: noise group, exposed only to noise; the noise and solvents group, exposed to noise and solvents; the noise control group and noise and solvents control group, no exposure. 	Human	Metal graphics	Brazil	-

Hughes & Hunting, 2013	<ul style="list-style-type: none"> - 4 exposure profiles: Noise with solvents, noise alone, solvents alone and neither noise nor solvents. - 503 workers from two Air Force Reserve sites. - 41 subjects did not meet the study inclusion criteria. 	Human	Aviation industry	USA	<p>Noise: Above OEL's</p> <p>Solvents: Below OEL's</p>
Rizk&Sharaf, 2010	<ul style="list-style-type: none"> - 110 workers in a fermentation plant divided into two groups. - Group A (50 workers,) exposed to noise only, group B (60 workers) exposed to noise and mixture of organic solvents, - Control group (group C; 30 workers) were neither exposed to noise nor organic solvents. 	Human	Fermentation plant	Egypt	-
Chang, Shih, Chou, Chen, Chang, & Sung, 2003	<ul style="list-style-type: none"> - 131 men with exposure to noise and CS2 in a viscose rayon plant. - 105 men in the adhesive tape and electronic industries who were exposed to noise only - 110 men employed in the administrative office of the rayon plant who were exposed to low noise and no CS2. 	Human	Viscose rayon manufacturing	Taiwan	<p>Noise: Above OEL's</p> <p>Solvents: Above OEL's</p>
Metwally, Aziz, Mahdy-Abdallah, Said AbdElGelil, & El-Tahlawy, 2012	<ul style="list-style-type: none"> - 3 groups. - 70 workers exposed to noise only, the second group consisted of 93 workers exposed to organic solvents and noise, and the control group included 59 individuals exposed to neither noise nor organic solvents. 	Human	Painting production	Egypt	<p>Noise: Within OEL's</p> <p>Solvents: Below OEL's</p>