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OCCUPATIONAL HEARING LOSS AMONG WORKERS EXPOSED TO INDUSTRIAL CHEMICALS AND NOISE: A STUDY IN A PAINT COMPANY AND AMONG AUTOMOBILE SPRAYERS IN GHANA

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A RESEARCH DISSERTATION SUBMITTED TO THE

SCHOOL OF BIOMEDICAL AND ALLIED HEALTH SCIENCES,
COLLEGE OF HEALTH SCIENCES,

UNIVERSITY OF GHANA



IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE MASTERS OF SCIENCE IN AUDIOLOGY

JULY 2014

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DECLARATION

I **DEBORAH TETTEH** do hereby declare that this thesis which is being submitted in fulfillment of the requirements for the Master of Science degree in Audiology is the result of my own research performed under supervision, and that except where otherwise other sources are acknowledged and duly referenced, this work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

I hereby give permission for the Department of Audiology, Speech and Language Therapy to seek dissemination/publication of the dissertation in any appropriate format. Authorship in such circumstances to be jointly held between me as the first author and the project supervisors as subsequent authors.

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DEDICATION

The work is dedicated to Almighty God who has been my help in ages past.

Dedication is also extended to my late Dad, Michael Nii Sodjah Tetteh: Daddy I miss you dearly

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ACKNOWLEDGEMENTS

Firstly I would like to acknowledge the almighty God for his immense grace towards this project. Secondly to my supervisors, Prof. G.K. Amedofu and Dr. S. Anim-Sampong for their incalculable intellectual contributions throughout the thesis process. I would also like to thank Dr. Neal Boafo and Prof. J. Ribera for their time and contribution towards this research work.

Thanks again to the audiology department of Korle Bu teaching hospital who willing shared some equipment with me. To the Department of Audiology, Speech and Language Therapy of the University of Ghana School of Biomedical and Allied Health Sciences, I want to render many thanks for giving me all the necessary equipment and tools for my study. To their friendship and encouragement towards the completion of the thesis, I thank my course mates and junior colleagues, Willie, Tony and Ray.

A special thanks to the staff of Bamson Industry Limited and for the five automobile spraying garages within the vicinity of Mataheko, Accra for giving themselves willing as participants for this study.

And finally to my family and friends, your care and support in physical and financially has been really appreciated. To my husband, Bobby, thanks for your unceasing love, encouragement and emotional support! It broke many barriers and obstacles.

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TABLE OF CONTENTS

DECLARATION ..... **i**

DEDICATION ..... **ii**

ACKNOWLEDGEMENTS ..... **iii**

LIST OF FIGURES ..... **vii**

LIST OF TABLES ..... **viii**

LIST OF ABBREVIATION AND DEFINITION OF TERMS ..... **ix**

ABSTRACT ..... **xii**

CHAPTER ONE: INTRODUCTION **1**

1.1 BACKGROUND 1

1.1.1 Auditory and Physiology of Hearing 2

1.1.2 Hearing Loss 5

1.1.3 Overview on Noise 6

1.1.3.1 Ototraumatic of Noise 7

1.1.3.2 Mechanism of Ototraumatic Effect of Noise 8

1.1.4 Overview on Industrial Chemicals 9

1.1.4.1 Organic Solvents 9

1.2 PROBLEM STATEMENT 16

1.3 SIGNIFICANCE OF THE STUDY 17

1.4. AIMS 17

1.5 OBJECTIVES 18

1.6 RESEARCH QUESTIONS/HYPOTHESIS 18

CHAPTER TWO: LITERATURE REVIEW **19**

2.1 INTRODUCTION 19

2.2 HEARING LOSS DUE TO NOISE EXPOSURE ALONE IN OTHER OCCUPATIONAL SETTINGS 19

2.3 HEARING LOSS DUE TO EXPOSURE TO SOLVENTS ALONE IN OTHER OCCUPATIONAL SETTINGS 23

2.4 SYNERGETIC EFFECT OF NOISE AND SOLVENTS ON HEARING IN OTHER OCCUPATIONAL SETTINGS 25

2.5 HEARING LOSS DUE TO EXPOSURE SOLVENT ALONE IN PAINTS AND AUTOMOBILE GARAGES 28

University of Ghana http://ugspace.ug.edu.gh

2.5 SYNERGETIC EFFECT OF NOISE AND SOLVENTS ON HEARING IN PAINT INDUSTRY AND AUTOMOBILE GARAGES 29
CHAPTER THREE: METHODOLOGY 31
3.1 INTRODUCTION 31
3.2 STUDY DESIGN 31
3.3 STUDY SITES 32
3.4 STUDY POPULATION 32
3.5 SAMPLE SIZE AND SAMPLE TECHNIQUE 34
3.6 INCLUSION AND EXCLUSION CRITERIA 34
3.6.1 Exclusion Criteria 34
3.6.2 Inclusion Criteria 34
3.7 INSTRUMENTATION AND MATERIALS 35
3.7.1 Otoscopy 35
3.7.2 Immittance Device Tympanometry 35
3.7.3 Sound Level Meter 36
3.7.4 Pure Tone - Computer-Based Audiometer (Kudu Wave 5000) 36
3.8 EXPERIMENTAL AND DATA COLLECTION PROCEDURE 38
3.8.1 Interviews 38
3.8.2 Physical Examination and Immittance Audiometry 38
3.8.3 Solvent Exposure Survey and Assessment 39
3.8.4 Noise Exposure Survey and Assessment 39
3.8.5 Pure Tone Audiometry 40
3.9 DATA ANALYSIS 40
3.10 ETHICS 41
CHAPTER FOUR: RESULTS 42
4.1 INTRODUCTION 42
4.2 CHARACTERISTICS OF THE POPULATION 42
4.3 EXPOSURE CRITERIA AT WORK SITES 44
4.4 PREVALENCE OF HEARING LOSS AMONG THE GROUPS 45
4.4.1 Hearing loss differences among groups. 46
4.5 PREVALENCE OF HEARING LOSS USING ODD RATIO 46
CHAPTER FIVE: DISCUSSION 51

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5.1 INTRODUCTION 51
5.2 RESEARCH QUESTION AND HYPOTHESES 51
5.2.1 Research Question 51
5.2.2 Hypothesis 52
CHAPTER SIX: CONCLUSIONS,RECOMMENDATIONS AND LIMITATIONS 56
6.1 INTRODUCTION 56
6.2 CONCLUSIONS 56
6.3 RECOMMENDATION 57
6.4 LIMITATION OF THE STUDY 57
REFERENCES 59

University of Ghana http://ugspace.ug.edu.gh

LIST OF FIGURES

Figure 1.1: Major parts of the peripheral auditory system…….. …. …….. 3

Figure 1.2: Cross section of the cochlea……...4

Figure.1.3: Percentage of industrial user of organic solvents……..12

Figure 3.1: Block Diagram of the Immittance Device…….35

Figure 3.2: Block Diagram of a Kudu Wave 5000 Computerized Audiometer……..37

Figure 4.1: Odd ratio of hearing loss among groups…….…..47

Figure 4.2: Prevalence of high and low frequency hearing loss among groups……..48

Figure 4.3: Mean binaural average of high and low frequency among groups……...49

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LIST OF TABLES

Table 1.1: Main industrial uses of specific solvents……..…11

Table 4.1: Demographic characteristics of population……..43

Table 4.2: Criteria for determining exposure status……..44

Table 4.3: Percentages of hearing loss among groups……...45

Table 4.4: Descriptive differences among Groups…….46

Table 4.5: Group differences of prevalence of hearing loss using ANOVA……..46

Table 4.6: Prevalence of hearing loss among groups using odd ratio……...47

Table 4.7: Inter-group comparison of hearing loss……...48

Table 4.8: Differences of high frequency average among groups……50

Table 4.9: Differences of low frequency average among groups…….50

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LIST OF ABBREVIATION AND DEFINITION OF TERMS

AAA	American Academy of Audiology
ANSI	American National Standards Institute
ASHA	American Speech-Language-Hearing Association
CIHL	Chemical induced hearing loss
dBA	decibel average
dB HL	decibel hearing level
DPOAE	Distortion product otoacoustic emissions
EAC	External auditory canal
EHF	Extended high frequency
EMT	Electromechanical transduction
IHC	Inner hair cell
MET	Mechanoelectrical transduction
MSDA	Material and safety data sheets
NEG	Noise only exposed group
NIHL	Noise-induced hearing loss
NSEG	Noise and solvent exposed group
OAE	Otoacoustic emissions
OHC	Outer hair cell
PEL	Permissible exposure limits
RCNHL	retro cochlear hearing loss
SEG	Solvent only exposed group
SNHL	Sensorineural hearing loss

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TTS	Temporary threshold shift
UNSG	Un- exposed to noise or organic solvents group

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DEFINITION OF TERMS

Hearing loss: threshold above 25 dB and above.

Prevalence: occurrence of occupational hearing loss as a result of exposure to solvents and/or noise.

Un-exposed to noise or chemical group (UNCG): Workers who are not occupationally exposed to noise or organic solvents.

Exposed to noise and chemical group (NCEG): Workers who are occupationally exposed to both noise and organic solvents.

Noise only exposed group (NEG): workers who are occupationally exposed to noise only.

Noise Induced Hearing loss (NIHL): Hearing loss as a result of exposure to noise.

Chemical induced hearing loss (CIHL): Hearing loss as a result of exposure to chemicals

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ABSTRACT

Background: Occupational hearing loss is a general term used to describe hearing loss that occurs in work environments. Noise and industrial chemicals such as organic solvents are two main toxic acoustic disturbance and substances that can have adverse effects on the auditory system and consequently induce hearing loss. This is corroborated by experimental studies on both animal and human which confirm ototoxic effects of industrial organic solvents and noise. Worldwide, several industries employ industrial chemicals in the manufacture of paints. In Ghana, there are several work environment which employ organic solvents in the manufacture and use of paints. Presently, published studies have not been done in Ghana on the ototoxicity of industrial chemicals and noise on hearing loss.

Aim: This study aims to evaluate the effect of occupational exposure to noise and industrial chemicals on hearing loss in a paint company and among automobile sprayers. This study is aimed at creating awareness of the effects of industrial chemicals and noise exposure on the peripheral auditory system of humans and find if significant occupational hearing loss exist among workers exposed to industrial chemicals and noise.

Methodology: A cross-sectional study comprising case-control sample of 115 workers was selected purposively and conveniently from a paint company and five automobile garages who were either exposed to or not exposed to industrial chemical or and noise. The procedure adopted included noise survey, industrial chemical survey, case history, otoscopy, tympanometry and standard pure-tone audiometry.

Results: The odds of hearing loss found in the group exposed to both noise and solvents was 1.096 (95% CI.0.340-3.532) higher than those in the noise only group (0.062 odds, 95% CI.0.016-1.108) as compared to the control group.

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Conclusion: This suggests that there is an association between occupational exposure to both industrial chemicals and noise with hearing loss.

Keywords: ototoxicity, ototraumatic, chemical induced- hearing loss, noise induced- hearing loss

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Occupational hearing loss is a general term used to describe hearing loss that occurs in the work environment as result of exposure to intense noise and other agents such as chemicals. Occupational hearing loss was formerly referred solely as occupational noise- induced hearing loss. However with much attention on holistic approach in studying other factors on the health among workers in the work environment, investigators has brought the light of occupational chemical- induced hearing loss under the umbrella of occupational hearing loss upon further investigation done on other chemicals found in the work environment. Among these chemicals investigated are organic solvents, pesticides, metals such as Arsenic, mercury, and gases such as carbon monoxide.

Worldwide, workers from factories and manufacturing companies experience these types of hearing loss. Notably is the paint manufacturers and paint users such as car sprayers. In the use and manufacturing of paints, many industrial chemicals are used notably is organic solvents which comes in various forms. According to NIOSH (2001), Approximately 30 million workers are exposed to hazardous noise on the job and an additional nine (9) million are at risk for hearing loss from other agents such as solvents and metals. Noise causes occupational noise-induced hearing loss whereas chemicals exposure causes occupational chemical- induced hearing loss. Normal hearing results in a well-functioning human auditory system. This system comprises well-structured specialized cells that function independently and later in combination

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to enhance normal hearing. A basic background of the physiological basis of the peripheral auditory system, hearing loss and an overview of noise and industrial chemicals is vital in understanding this study.

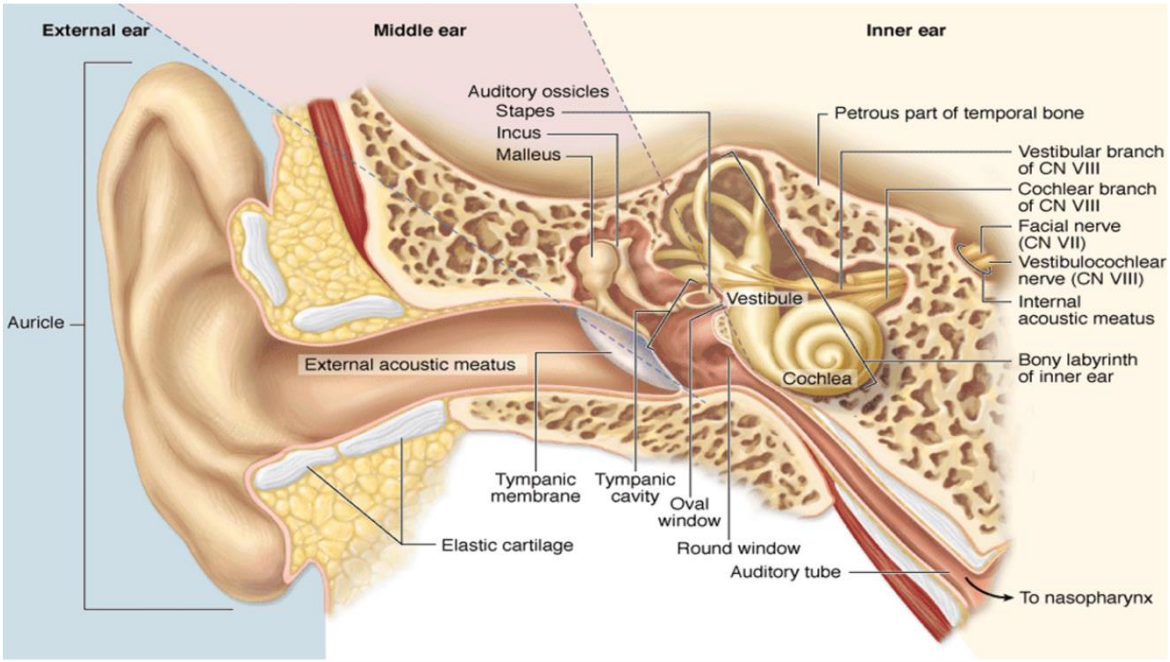
1.1.1 Auditory and Physiology of Hearing

The auditory system is composed of the outer ear, the middle ear, the inner ear and its neurological pathways as shown in Fig. 1. Anatomically, the outer ear includes the auricle and the ear canal, while the middle ear consists of the ear drum (tympanic membrane) and three tiny bones (stapes, incus and malleus), and the inner ear comprises the sensory organs of hearing and balance.

Functionally, the auditory system acts a human transducer and converts mechanical energy to bioelectrical signals, and codes the signal frequency, intensity and timing information content. Audible acoustic energy (sound) entering the auricle and into the external acoustic meatus places the tympanic membrane and the ossicles (malleus, incus and stapes) into vibration to convert acoustic energy to mechanical energy. As an impedance-matching transformer, the middle ear transfers air vibration into fluid medium. The cochlea consists of a membranous labyrinth within a bony shell (the osseous labyrinth) that is coiled into approximately 2 ½ turns (Yost, 2007). The cochlea has three main ducts: the superior scala vestibule, the central scala media (sometimes called cochlear duct; and the inferior duct called scala tympani. The Reissner‘s membrane separates the scalavestibuli and scala media as the basilar membrane, which is narrow and stiff near the basal end and progressively wider and more flexible toward the apex forms the boundary between scala media and scala tympani.

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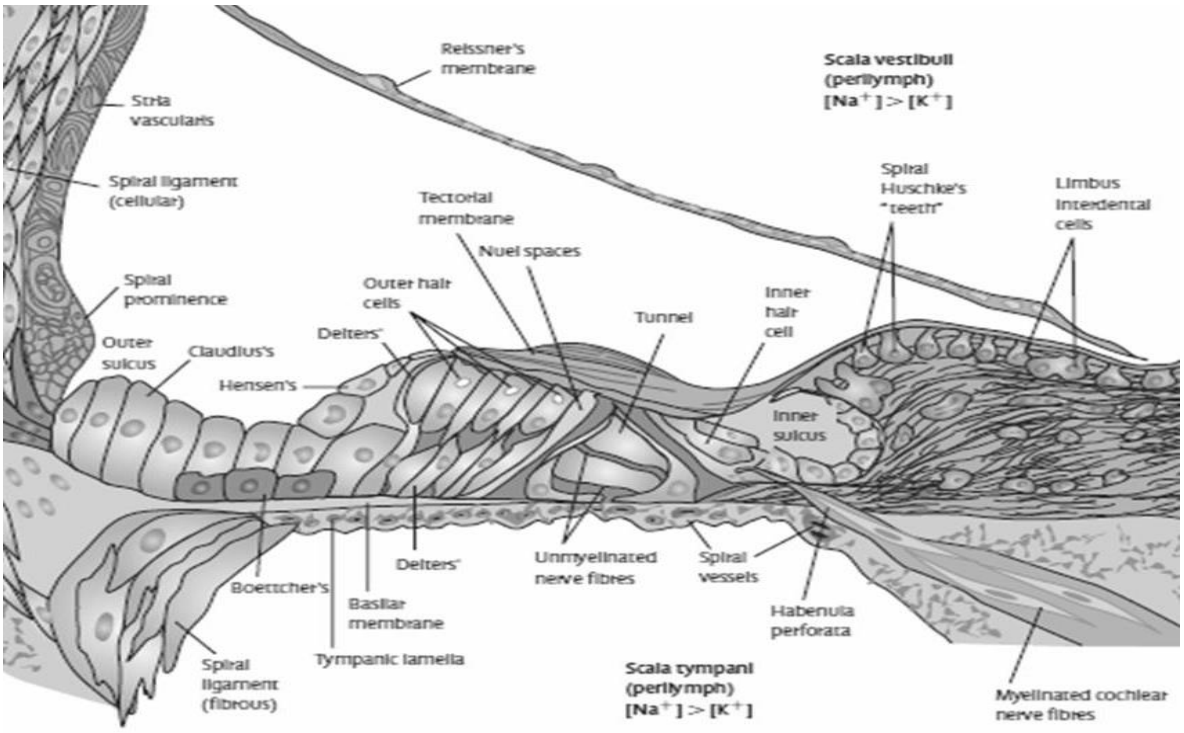
(Adapted from Neisser, 2000)

Figure 1.1: Major parts of the peripheral auditory system

The movement of the stapes footplate against the oval window membrane produces longitudinal waves within the cochlear fluids stimulating displacement of the basilar membrane. The basilar membrane stiffness and mass gradients causes it to vibrate in specific frequency patterns. Higher frequency tones occur at the basal end of the cochlea whiles maximal vibration for lower frequency tones occurs near the apex of the cochlea.

On top of the basilar membrane is the organ of Corti which contains a single row of inner hair cells (IHCs) and many rows of outer hair cells (OHCs). The Deiters, pillar, Hensen, Claudius, and Boettcher‘s cells (Fig. 2) are the supporting cells of the inner and outer cells. In particular, Dieters and Hensen cells have been known to be of particular importance to the outer hair cells (Musiek & Baran, 2007).

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(Adapted from Gates & Mills, 2005)

Figure 1.2: Cross section of the cochlea

The inner hair cells are flask shaped whereas the outer hair cells are tube-like. Both types have rows of different sized stereocilia protruding from the cuticular plates at their top ends (Gelfand, 2006). Protruding from the apical surface of each hair cell are stereocilia-axially-directed actin-filled microvilli with a myosin cap (McFadden, 2007). The stereocilia of the OHC only are embedded in the tectorial membrane. The stereocilia are arranged in rows based on height so that the shortest row is located on the modiolar side of the hair cell. They are connected via tip links which connect the tips of the shorter stereocilia to the next taller stereocilia, and lateral links, believed to tie adjacent stereocilia together enabling them to move as a unit (Pickles et al., 1984). These tip links are responsible for opening and closing mechanoelectrical transduction (MET)

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channels located near the tip of each stereocilia, which occurs with deflection of the hair cell bundle towards or away from the tallest stereocilia respectively.

The deflection of the stereocilia happens in response to radial shearing between the reticular lamina and the tectorial membrane with displacement of the basilar membrane. Each time the basilar membrane moves towards scalavestibuli, the MET channels open resulting in an influx of potassium (K+) ions from the endolymph in scala media into the hair cells. Movement of the basilar membrane towards scala tympani results in closure of the MET channels (Alchin, 2010). This cyclical flow of K+ into the hair cell produces a fluctuating receptor current and causes cyclic changes in membrane potential. The influx of K+ into the inner hair cell causes the cell to depolarise and release neurotransmitter, which initiates an action potential in the primary afferent neurons. Also, changes in membrane potential of OHCs produce cyclical changes in cell length via the protein prestin (Brownell et al, 1985; Liberman et al., 2002). This acts to cancel friction and increase the amplitude of the basilar membrane vibration by approximately 1000-fold (or 60 dB), particularly in the higher-frequency regions of the cochlea (Patuzzi, 2009). This mechanism is referred to as the active process and is a form of electromechanical transduction (EMT) (Dallos, 1992). The OHCs are very weak to mechanical and chemical reactions which will cause high frequency hearing loss.

1.1.2 Hearing Loss

Hearing is one of the important means of human communication which depends on complex sound analysis and transmission within the outer, middle, inner, auditory nerve and subsequent processing of the acoustic signal in the brain.

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A disorderly outburst to the anatomy and physiology of this auditory system results in the loss of hearing sensitivity. Some notable causes to hearing loss are exposures of excessive noise and organic solvents employed in certain occupational settings industries such as the paint industry, textile industries and paper manufacturing industries. Solvents cause chemical poisoning in the structure whereas noise causes mechanical damage (Sliwińska-kowalska et al., 2007). These chemicals cause sensorineural hearing loss (Barregard and Axelsson 1984), retrocochlear hearing loss (Hormes, Filley et al., 1986), and lesions in the higher auditory pathways (Moshe et al., 2002). Below is the overview of noise and industrial chemicals.

1.1.3 Overview on Noise

Virtually, noise is everywhere. Noise can be undesired and unwanted within a frequency band. Noise can be defined in its duration, frequency spectrum measured in Hertz. Historically, hearing loss caused by noise was dated from the Bronze Age. Discovery the use of metals like bronze and iron, for the production of weapons, noise induced hearing loss was introduced to man after these metals are beaten, hammered and forged creating impact noise. Noise poses threat to many occupational industries where its level exceeds the normal level. Many studies have shown that pollution of noise can cause discomfort or adverse health effect on workers. (Amedofu, Brobby, Ocansey, 1998; Boateng and Amedofu, 2004; Hassan and Beg, 1994). This adverse effect includes non-auditory effects such as elevated blood pressure, stress, tinnitus, reduced performance, sleeping difficulties, annoyance and auditory effect which includes acoustic trauma, Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTT) (Miller, 1971). Acoustic trauma is the brief exposure to a high level noise which results in an instant, severe and permanent hearing loss. Temporary threshold shift on the other hand, is an increase in the threshold of hearing following noise exposure which recovers gradually. Permanent threshold

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shift refers to the continuing loss of hearing threshold following a repeatedly high intensity noise over some period. Among industry workers, permanent threshold shift is found as occupational noise- induced hearing loss (NIHL).

Occupational noise induce-hearing loss is hearing loss that is a function of continuous or intermittent noise exposure and duration, and which usually develops slowly over several years. (ACOEM, 2012).Noise induced hearing loss (NIHL) is the most serious health effect among all these which results to irreversible damage to the delicate hearing mechanisms of the inner ear. Long-term exposure to loud sounds of slightly lower intensity, such as factory noise can also cause noise-induced hearing loss (Yaremchuk et al., 1997).Noise is a major health hazard in occupations where its level exceeds the normal level. Workers exposed to noise levels above 82 dB(A) are at risk for NIHL, and those exposed to levels above 90 dB(A) are at high risk (Phillips et al. 2007). In Ghana, noise levels have been known to exceed 90 dBA in industries such as the corn mills causing NIHL (Boateng and Amedofu, 2004).

1.1.3.1 Ototraumatic of Noise

Clinically, ototraumatic of noise is characterized by having a bilateral sensorineural hearing loss. The first sign is a “notching” of the audiogram at the high frequencies of 3000, 4000, or 6000 Hz with recovery at 8000Hz. (McBride & Williams, 2001) The notch usually develops at one of these frequencies affecting adjacent frequencies with continued noise exposure. Effect of age reduces the prominence of the “notch.” It is difficult to distinguish effects of noise from age-related hearing (presbycusis) without referring from previous audiogram when dealing with older patients. (Consensus Conference, 1990). This notching is in contrast to presbycusis, which also

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produces high-frequency hearing loss but in a down-sloping pattern without recovery at 8000 Hz (Coles, Lutman and Buffin, 2000).

Exposure to intense noise traumatizes hair cells in the inner ear (Bohne**,** Harding and Lee**,** 2007). The mechanism of noise-induced hearing loss is well known unlike organic solvents and can be explained by the mechanism of permanent threshold shift. In the mechanism, there are both morphological and molecular definitions in explaining noise induced hearing loss. Morphologically, the hair cells in the inner ear are physically damage and overstimulated. This triggers metabolic activity due to over stimulation leading to outer hair cell death. (Henderson et al., 2006). Studies have shown that hair cells can die through different pathways (Bohne et al., 2007; Hu et al., 2002) including apoptosis which is an active mode of cell death that requires energy supply, and necrosis, a passive mode of cell death due to early disintegration of cells. In particular, these two distinct modes of cell death differ substantially in their morphological and biological characteristics (Hu, 2009).Whereas apoptosis makes cell shrink, necrosis make cell turbid structurally. Biologically, cells that die through apoptosis activates group of enzymes that digest cellular structures.

1.1.3.2 Mechanism of Ototraumatic Effect of Noise

Generally, with mechanism of permanent hearing loss, the initial hair cell death occurs at a location along the cochlea that is related to the frequency place of the damaging sound which may be due to mechanical injury directly rupturing cells and inducing necrosis (Henderson et.al, 1999). In this, the plasma membrane, the cell itself and that of the nucleus swells due to influx of water and eventually dies. The damage progress to spread outwards into the apical region (low frequencies) but more conspicuous in the basal region (higher frequencies) leading to progressive

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hair cell death. The progressive loss seems to occur through apoptosis where there is activation of enzymes. (Forge, 2012).

Progressive loss of hair cell has been explained mostly by biological and molecular mechanisms. Much attention of the mechanism has been given to the role of oxidative stress (Henderson et al, 2006). High levels of oxidative metabolism following overstimulation of the hair cell generate excessive free-radicals which stress the cell and gradually leading to their death. Oxidative stress targets many cellular structures that are vital for the cell's survival, such as the plasma membrane, the mitochondria, and the nuclei of cells (Hu, 2009). In a review to explain the oxidative stress of the cochlea, Poirrier et al., (2010) discussed that; following noise exposure, nitrotyrosine, a marker of reactive nitrogen species formation, shifts from supporting cells to outer hair cells in the organ of corti. Adding to it, reactive oxygen species acts in the peroxidation of polyunsaturated fatty acids. Again they discussed that markers of lipid peroxidation have been demonstrated in the hair cells, supporting cells, spiral ganglion neurons and striavascularis after noise trauma. At the enzymatic level, noise exposure increases nicotinamide adenine dinucleotide phosphate oxidase activity in the cochlea and targeted deletion of superoxide dismutase increases the susceptibility to acoustic injury, highlighting the importance of superoxide anion in noise-induced damage.

1.1.4 Overview on Industrial Chemicals

1.1.4.1 Organic Solvents

Organic solvents are simple liquids used to dissolve other substances. Industrially, organic solvents are colourless, have at least one carbon and one hydrogen atom, low molecular weight, and high lipophilicity and volatize easily and have strong odour which are normally extracted or

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manufactured for chemical use. According to AAE Chemie (2014), an international supplier of industrial chemicals, Organic solvents can be classified into three groups based on their chemical structure: Oxygenated solvents – substances like alcohols, ketones, esters, and glycol ethers fall into this category. These types of solvents are used when high solvency power is needed. They can also be used for water based formulations such as detergents and water based paints. Hydrocarbon solvents – these are paraffinic, aliphatic and aromatic hydrocarbons. They are typically used in applications where there is low solvency power and good separation from water is required. Halogenated solvents – this category consists of chlorinated hydrocarbon solvents (AAE, 2014). Toluene, styrene, xylene, trichloroethylene, carbon disulphide, n-hexane are some common solvents used in the industrial setting (Morata et al, 1994).

These solvents are used for electroplating, printing rubber manufacturing, wood stains, metal degreasing, and resins, paints manufacturing, pesticide manufacture, for rubber production and for pharmaceutical manufacturing. The largest demand for solvents comes from the paint and coatings industry; it relies on almost two million tons every year (AAE Chemie, 2014).In the paint industry, organic solvent appear as raw solvents, and in thinners and lacquers. During use, these solvents as well as their volatized form are inhaled and absorbed through the respiratory organs and through the skin. The uses of these industrial solvents and the percentages of industrial users are presented in Table 1.1and figure 1.1 respectively. According to Amedofu and Fuente (2008), about 80% of chemicals produced are used in industrialized countries and the remaining 20% in developing countries. Of this 20%, studies done in both animals and human mostly in the developed countries have shown that these industrial chemicals adversely affect hearing and balance and as such these studies have serious implications for developing countries.

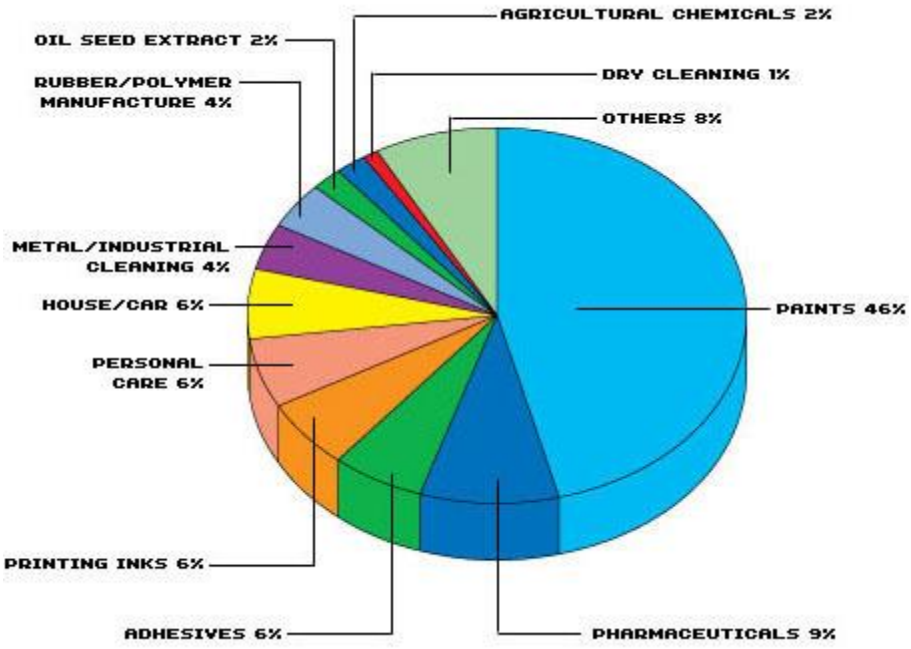
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Table 1.1: Main industrial uses of specific solvents

Organic Solvent	Industrial Uses
Toluene	Adhesive manufacture, electroplating, laboratory chemicals, machinery manufacture and repair, metal degreasing, paint manufacture, paint stripping, paper coating, pharmaceuticals manufacture, pesticide, printing, rubber, wood stains and varnishes and foot wear manufacture.
Styrene	Pulp and paper manufacture and in plastics, resins, coatings and paints manufacture.
Xylene	Electroplating, laboratory chemicals machinery manufacture and repair, paint manufacture, paint stripping, paper coating, pesticide manufacture, pharmaceuticals manufacture
Trichloroethylene	Electroplating, integrated iron and steel manufacture and repair, metal degreasing

(Adapted from Amedofo and Fuente, 2008)

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Source: AAE Chemie 2014

Figure 1.3: Percentage of industrial user of organic solvents

1.1.4.2 Ototoxicity of Industrial Chemicals-Solvents

Solvent ototoxicity means ear poisoning and it describes the poisoning of the inner ear by exposure to organic solvents. In the process of solvents ototoxicity, the solvents contaminate the tissue of the inner ear rather the ear fluids in the inner ear unlike the ototoxicity of some other agents such as ototoxic drugs.

A possible effect of toluene on rats was first published in 1983 by Pryor, et al. Several studies have reported high frequency hearing loss and accompanying cochlear changes in weanling rats exposed to toluene. However, the noise levels generated by the exposure chambers were not always reported, and the role played by this confounder was not explored. Morphologic examination of the toluene-exposed rats' cochleae revealed loss of or damage to hair cells in the

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basal portion of the cochlea. Low concentration of toluene affects the extra medullary and high medullary part of the auditory pathway (Vrca et al., 1996). These studies with these animals have been repeated and most studies have demonstrated that rats simultaneously exposed to both toluene and noise suffer a more severe hearing loss than the summated hearing loss obtained from an equivalent exposure level to each agent alone (Lataye and Campo, 1997; Brandt-Lassen et al., 2000). Research has also demonstrated that rats simultaneously exposed to both toluene and noise suffer a more severe hearing loss than the summated hearing loss obtained from an equivalent exposure level to each agent alone (Brandt-Lassen et al., 2000).

Styrene causes high frequency hearing threshold (Muijser et al., 1988). Styrene causes permanent and progressive damage to the auditory system and its hearing loss is species specific (Campo et al., 2001). Low (3000 and 4000 Hz), mid (16000 Hz), and high frequencies (32000 Hz and above) have been affected after styrene exposure in rats. The effects have been observed in short term exposures to high concentration and lower concentrations to that of longer-term exposures. Primarily, trichloroethylene is used for degreasing and also as a paint remover. It can also be used as a drying agent in the paint and plastic industries. Trichloroethylene causes mid frequency and high frequency hearing loss at concentration of 2000ppm (Rebert et al., 1991). Like other solvents, trichloroethylene has ototoxic effects on rats (Jaspers, Muijser and Lammers, 1993).

Solvent exposure results in chemical hearing loss. Cohort studies have shown that up to 23% of solvent exposed individuals develop chemical induced hearing loss (CIHL) versus 5-8% in a non-chemical work environment (Bergstrom and Nystrom 1986). Some clinical characteristics of chemical induced-hearing loss are: bilaterally symmetrical, irreversible, 3kHz-6kHz onset,

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usually cochlear or with some cochlear component (Morata and Lemasters, 1995). The combined effects of the noise and the solvents have been known to cause higher incidence of sensorineural hearing loss (SNHL), retrocochlear hearing loss (RCNHL), and lesions in the higher auditory pathways as observed by Barregard and Axelsson (1984), Hormes et al., (1986), and Moshe et al., (2002).

Morata and Lemasters (1995) emphasized that the adverse auditory effects of chemicals such as organic solvents are due to a combination of ototoxicity and neurotoxicity. Ototoxicity induces outer hair cell (OHC) dysfunction in the cochlea and is of more concern to the peripheral auditory site; whereas neurotoxicity induces central auditory dysfunction and creates concern to the central auditory site. Unlike the ototoxicity of some drugs such as aminoglycosides and cisplatin, organic solvent-induced ototoxicity affects the tissues of the hair cells rather than the inner ear fluids and during exposure to organic solvents, poisoned intrusions emerges at the level of the inner ear (Campo et al, 1999; Campo et al 2001). Some research studies have shown that organic solvents are generally ototoxic to the cochlea (Campo et al., 1997; Lataye et al, 2000; Sliwinska-Kowalska et al., 2003). The Dieters' cells are another target of organic solvents. (Chen et.al.,(2007); Chen, Tanaka and Henderson, 2008).

1.1.4.3 Mechanism of solvent-induced ototoxicity

Solvents may modify the membranous structures of OHCs making them more fragile and vulnerable to noise (Campo et al, 1999). Chemical analyses and clear observations of disrupted membranes of the cochlea of animals have shown that organic solvents use the outer sulcus which is the main intoxication route at reaching the OHCs (Campo et al.,2001).This constitute the structural mechanism of solvents. Much progress have been made on definition of the

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morphological characteristics of solvent induced ototoxicity and disease surveys have confirmed the solvents induced potency in humans over the past years .However the molecular mechanisms underlying solvent ototoxicity is not well known although the action of oxidative stress has been mentioned, there is no published data **(**Campo and Maguin, 2007).

In an attempt to make the concept of solvent induced hearing loss clear, Campo and Maguin (2007) in describing the mechanism of solvent ototoxicity, indicated that solvents which are aromatic pass through the stria vascularis in both metabolized and un-metabolized forms or from the spiral prominence, and diffuse through the lipid-rich membranes of the cubic cells constituting the outer sulcus so that no mechanical stress is involved before they impair the organ of corti. There is firstly, an alteration of the supporting cells like the Deiters and Hensen cells which may affect the K+ ionic concentrations around OHCs by modifying the re-uptake of K+ from the corticolymph, resulting in the generation of excessive K+ build up beneath the outer hair cells that might cause the poisoning. This is followed by lipid peroxidation of the membranous structures leading to serious disturbances of the cytoplasmic membrane of the OHCs resulting in cellular injuries, cell swelling, and early loss of cytoplasmic membrane. The general mechanism of the cochlea toxic process is thus contended as necrotic rather than an apoptotic phenomenon.

This background of the study above serves as the information that is essential to understanding the many conclusions given in the hearing loss as a result of exposure to organic solvent and noise.

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1.2 PROBLEM STATEMENT

In many developing countries, the effects of these chemical exposures are not detected early and its effects are undermined as the cause of hearing loss, whiles noise is taken mostly as the number one cause of hearing loss (Amedofu and Fuente, 2008). In Ghana, there are many industries where most workers are exposed to these chemicals and are fully unaware of the dangers posed to them regarding on their hearing. This is attributable to the relatively low levels of awareness and safety measures. Notably, paint users and paint manufactures are among the identified notable industries which employ the use of these chemical solvents which they inhale or absorb through the skin as well as emit high noise exposures through their machines which are ototoxic to the auditory system. Another problem related to this study is that occupational hearing health receives very little attention by health service planners due to the lack of statistics on the studies done in that area; hence knowledge of industrial chemicals and noise causing hearing loss is limited to workers who work with these ototoxic and ototraumatic agents.

A few studies have been done in the past on occupational hearing loss in Ghana with particular emphasis on the mining, sawmill, printing press, corn mills, stone crushing industries (Amedofu et al., 1998; Boateng and Amedofu, 2004; Kitcher et al., 2012). These research studies have however been concentrated on NIHLs leading to the need of regulation of noise in Ghana. Whereas noise is regulated in Ghana little is known of the regulation of organic solvents. In addition, no published studies on the combined effects of industrial noise and use of organic chemical solvents on the auditory system with respect to occupational hearing loss in Ghana have been done. Although there are existing laws and regulations regarding noise exposure levels

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(not more than 85 dBA), there is however, no law protecting workers in these industries against exposures hazardous chemicals on their hearing albeit their known dangers.

Therefore, it is imperative to conduct this study on NIHL and CIHL to investigate occupational hearing loss resulting from industrial noise and industrial chemicals in the paint industry and subsequently provide professional audiological and technical solutions to the identified and underlying problems.

1.3 SIGNIFICANCE OF THE STUDY

Clearly, this research may serve as a basic data to minimize the attendant medical problems for workers exposed to organic solvents and noise in combination. With this study, knowledge about legislation in Ghana may be enhanced regarding the permissible exposure limits (PELs) for ototoxic and ototraumatic agents such as solvents. Further, this research will promote audiology health care delivery by giving an insight on diagnostic and preventive measures in hearing loss. Also this research will pave way on the awareness of the effects of industrial chemicals on the auditory system. Furthermore, this study may be part of documents for further policy setting in the country especially laws governing work environments and may serve as basis when planning health services to the country.

1.4. AIMS

This research work was aimed at:

(1) investigating the prevalence of occupational hearing loss among workers exposed to both industrial chemicals and noise, noise only and those not expose to neither noise nor chemical in a paint company and among automobile sprayers.

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(2) comparing the characteristics and degree of hearing loss between the study groups.

1.5 OBJECTIVES

The objectives identified for achieving the aims of this research work include:

(1) determination of noise exposure levels of workers exposed to noise.

(2) survey the industrial chemicals used in the paint company and the automobile spraying garages.

(3) determination of the prevalence of hearing loss among participants using pure tone audiometry

1.6 RESEARCH QUESTIONS/HYPOTHESIS

The research study was stated as; In comparison to workers not exposed to chemical solvents and noise; do those who are exposed to both solvent and noise have higher odds of having hearing loss than noise exposed only?

HYPOTHESIS

1. Solvent and noise exposure group will have a higher prevalence of hearing loss than the noise only and control groups.

2. Prevalence of high frequency hearing loss will be higher than the prevalence of low frequency hearing loss among those with hearing loss

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CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Occupational hearing loss as a result of noise induced and organic solvents induced have been studied in different settings especially that of animals and humans. Broadly, this chapter will review general related studies on occupational hearing loss in other occupation settings due to exposure to noise and solvent and will narrow it down to studies done in paint industries and among paint users. The related studies review will involve human studies behind hearing loss due to exposure of industrial organic solvent alone, exposure of noise alone and exposure to both noise and organic solvent in combination.

2.2 HEARING LOSS DUE TO NOISE EXPOSURE ALONE IN OTHER OCCUPATIONAL SETTINGS

Exposure to noise has been found to have effect on the hearing level of workers in many occupational settings. In a study of Shakhatreh, Abdul-Baqi and Turk (2000), high prevalence rate of hearing loss was higher among textile workers exposed to noise. The study compared the prevalence rate of hearing loss at different levels of noise in a textile factory to find out the levels of hearing loss according to duration (years) of employment in the factory. Seventy workers exposed to different levels of noise were matched with 70 persons in the community who were not exposed to occupational noise. Noise levels dB (A) were measured at different locations in the factory. The prevalence rate of hearing loss was higher among the exposed group i.e. 30% in the exposed group and 8% in the non-exposed group. Hearing loss increased with increasing

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level of noise reaching 73% in the 95dB (A) area. Average hearing loss was highest amongst those who were employed for 25 years or more, reaching 39% dB (HL).The study placed the relative importance of hearing loss as a result of high level and duration of noise exposure.

Similarly in another textile factory, the effect of uncontrolled occupational noise exposure on unprotected workers was found to be higher among workers exposed to noise. Osibogun, Igweze and Adeniran (2000), observed this significant hearing loss among these textile workers in Lagos metropolis. Across-sectional sample of 204 textile workers was selected randomly from all sections (including the non-production areas), and was initially screened to exclude subjects with pathological middle ear as well as those currently working in sections classified as non-noise but who had been exposed to excessive noise in the past. The subjects were divided into 3 groups, based on the noise levels observed at their worksites using a sound level meter: the noise-exposed group (noise levels 90 dBA); the less-noise-exposed group (noise levels 85-90 dBA); and the non-noise-exposed group (noise levels 85 dBA). A comparative analysis of the data on hearing threshold levels using the pure tone audiometry of the 3 groups showed that the noise-exposed group had significantly elevated hearing threshold levels at all frequencies and in each age group, although the maximal threshold shifts were observed at the 4000 Hz frequency. They further observed that the hearing threshold levels for the noise-exposed group increased with the duration of noise exposure.

In Ghana, the impact of hazardous noise has not been constrained to only certain industries; it has been involved in many work sites. Amedofu (2002) for example observed noise induced hearing loss among 59 workers in a surface gold mining company in Ghana. Following a noise survey, case history, otoscopy and conventional pure-tone audiometry, two hundred and fifty two

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(252) workers were observed from the following areas; Pit, Processing, Ana Laboratory, Bore-hole and Mess area. These areas were surveyed for hazardous noise. The results showed that all the above areas except the mess area produced noise levels above 85 dBA. The workers in these areas were assessed using pure tone audiometry with 59(23%) having the classical noise-induced hearing loss (NIHL) at 4 KHz. It is also noted that out of 81 workers with a pre-employment history of noise exposure, 41(51%) had NIHL. NIHL also varied with regard to job location. The author concluded that factors not under the control of the company may affect the hearing of an employee.

Excessive levels of noise produced in industries poses as a pollution. Boateng and Amedofu (2004) found striking effects on the hearing capabilities of workers on industrial noise pollution and its effects on the hearing capabilities of workers. The procedure adopted included noise measurements, otoscopy, audiometric evaluation and assessment of medical history. The results showed that noise levels in cornmills and sawmills exceed 85dBA. The average noise level measured in the printing industry was 85dBA. It was also found that 23 %, 20 % and 7.9 % of workers in cornmills, sawmills and the printing industry have evidence of noise-induced hearing loss (NIHL). A highly significant correlation was found between noise exposure level, duration of exposure and the development of NIHL in corn mills and sawmills but not in the printers. The authors suggested that more specific intervention is required to protect workers exposed to such hazards at the work places.

A combination of the informal and formal occupation settings investigations has not been excluded here in Ghana. In a cross-sectional study to find out the prevalence rate of early NIHL

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among stone crushing workers, Kitcher, Ocansey and Tumpi (2012), investigated 140 workers from the stone crushing industry who were compared with a control group of 150 health workers.

Participants were evaluated using a structured questionnaire, which assessed symptoms of hearing loss, tinnitus, knowledge on the health hazards associated with work in noisy environment and the use of hearing protective device. Pure tone audiometric was used to assess participants hearing status and noise levels at the work stations of the stone workers and of the controls was measured. Subjective hearing loss occurred in 21.5% of the workers and in 2.8% of the controls. Tinnitus occurred in 26.9% of stone workers and 21.5% of controls, while 87.5% stone workers had sound knowledge on the health hazards of a noisy environment. Early NIHL in the left ear occurred in 19.3% of the stone workers compared with 0.7% in controls and in the right ear, it occurred in 14.3% of the stone workers and in 1.3% of the controls of *P* value<0.005. The prevalence of early NIHL among the stone workers, considering the total number of ears, was 33.6% compared with 2% in the controls. In a conclusion by the authors, emphasis was made on majority of the stone workers having sound knowledge of health hazards of working in a noisy environment.

Considering the findings above, it may be possible to argue that at higher level exposure, longer duration of noise and even with prior knowledge of the effect of noise on hearing noise affects the hearing of occupational workers. Like the exposure to noise alone, solvent exposure has been studied among industrial workers. The following section discusses hearing loss due to exposure to organic solvents alone.

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2.3 HEARING LOSS DUE TO EXPOSURE TO SOLVENTS ALONE IN OTHER OCCUPATIONAL SETTINGS

Solvent- induced hearing losses affecting higher frequency of hearing have been studied in many occupational setting. Most of these solvents studied normally appear as mixtures as many solvents can be found in these occupational settings. There are few studies done on single organic solvents. None the less, exposure to organic solvents in exclusion of the presence of noise exposure has led to many findings among workers.

Solvent as a risk value for hearing loss also has a high relationship with hearing loss. In a retrospective cohort study to examine the relationship between solvent exposure and hearing loss in US aluminium industry workers, Rabinowitz et al in 2007, found that organic solvent mixtures is a risk factor for high frequency hearing loss. The study involved 1319 workers aged 35 years or less at inception that were followed for 5 years. Study subjects were classified as ‘‘solvent exposed’’ or not, on the basis of industrial hygiene records of noise exposure linked with individual job histories. Study subjects already had baseline audiogram and make use of hearing protection devices. This ruled out noise exposure in affecting the study of mixtures of solvents alone. Subjects included coating operators on aluminium coating lines, maintenance workers who performed painting activities, and aluminium extrusion and foil operators who had a minimum of 4–6 years of audiometric follow-up, and at least three audiograms performed during that period. Hearing levels were assessed using the results of pure tone audiometry and the formal audiogram were reviewed especially those exposed to these mixtures of solvents. For each individual, the rate of change (decibels/year) in the binaural average of hearing threshold levels at the noise-sensitive frequencies of 3, 4 and 6 kHz was determined over the follow-up period. Hearing loss was defined either in terms of this continuous rate of change (dB/year) or

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dichotomously as an annual rate of change greater than 1 dB/year at these frequencies. They found out that workers in solvent-exposed jobs had an increased risk of high frequency hearing loss, even after adjusting for demographic risk factors and noise exposure concluding that there is a relationship between exposure to organic solvent and hearing loss.

None the less, single organic solvent exposure appears to have similar effect on hearing Recently in the evaluation of the peripheral and central auditory system of a histology laboratory 46-year – old worker exposed to xylene for twenty years, presented with bilateral mild sensorineural hearing loss at an initial assessment, Fuente, McPherson and Hoodt in 2012 observed a similar results of hearing loss for the same subject. Solvent exposure survey revealed that the subject had a low concentration exposure to xylene than the PEL for xylene in US OSHA norms for airborne xylene exposure as well as low exposure to noise. Further audiological test were done after behavioral Pure-tone audiometry. It was revealed that the worker had mild bilateral sensorineural hearing loss with worst hearing threshold at frequencies 3, 4, and 6 kHz for both ears and normal hearing threshold at a frequency of 8. The study concluded that xylene exposure may induce cochlear hearing loss, and xylene may induce hearing loss over a wide range of frequencies (1-6 kHz) as measured by pure-tone audiometry. Further, the authors suggested questions concerning history of solvent exposure should be part of the routine patient examination undertaken by audiologists.

These findings brings the predictive ability of exposure to solvents alone in causing a hearing loss paying particular attention to even low exposure levels and frequencies of hearing threshold in regard to pure tone assessment.

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2.4 SYNERGETIC EFFECT OF NOISE AND SOLVENTS ON HEARING IN OTHER OCCUPATIONAL SETTINGS

Noise has been known to addictive and synergistic to exposure to organic solvents although the possible synergism of combined exposure to solvents and noise on hearing has not been consistently identified in human studies. Morata, Fiorini et al (1997) found no statistical interaction between toluene and noise in inducing hearing loss with rotogravure printing workers who had, had a relatively short duration of noise exposure, it was likely that they were not exposed long enough to allow for any noise effects to be detectable. The study however had forty nine percent (49%) of the workers having hearing loss.

In a similar way, Sliwińska-Kowalska et al., (2003) investigated the effects of occupational exposure to styrene and combined exposures to styrene and noise on hearing. In the study**,** group, comprising of 290-yacht yard and plastic factory workers, was exposed to a mixture of organic solvents, having styrene as its main compound. The reference group, totaling 223 subjects, included (1) white-collar workers, exposed neither to solvents nor noise and (2) metal factory workers, exposed exclusively to noise. All subjects were assessed by means of a detailed questionnaire and underwent otorhinolaryngological and audiometric examinations. Factors adjusted for were: age, gender, current occupational exposure to noise, and exposure to noise in the past. The mean hearing thresholds--adjusted for age, gender, and exposure to noise--were significantly higher in the solvent-exposed group than in the unexposed reference group at all frequenc(ies) tested. A positive linear relationship existed between an averaged working life exposure to styrene concentration and a hearing threshold at the frequencies of 6 and 8 kHz. This study provides the epidemiological evidence that occupational exposure to styrene is related to an increased risk of hearing loss. Combined exposures to noise and styrene seem to be more

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ototoxic than exposure to noise alone**.** In terms of odd ratio, Sliwinska-Kowalska et al. in 2004 found that the odds ratio (OR) for hearing loss increased in the noise and solvent group by 5 whiles the noise-only group was approximately 3 when effects of exposure to noise and mixture of organic solvents on hearing was investigated in dockyard workers.

Recently, in an investigation to find out the hearing defects among workers exposed to mixtures of solvents and noise at levels considered safe in industrial settings, Fateheya et al., (2012) reported that sensory neural hearing loss occurred in subjects with combined exposure to noise and solvents at much lower levels recommended by Egyptian Environmental Law compared to the subjects with sole exposure to noise. The study comprised three groups. The first one included 70 workers exposed to noise only during their work in the carpenter, air compressor, and engineering departments in the National Research Center ,the second group consisted of 93 workers exposed to mixture of solvents, mainly aromatic in nature, as xylene, toluene, and thinner and noise in one of the Egyptian painting production plant from different industrial sections, and the control group included 59 individuals selected randomly from different administrative clerk sections in the National Research Center, who were neither exposed to noise nor exposed to organic solvents .

The three groups were matched for age, socioeconomic status, and smoking habit. With the help of a questionnaire, the personal data, smoking habits, detailed history of current and previous occupational jobs, history of chronic drug intake, and any previous ear operation or pus discharge or hearing problems were obtained for the workers. Subjects with history of chronic illness as diabetes mellitus, hypertension were excluded from the study. All of the subjects underwent pure tone audiometry at the frequencies of 0.5, 1, 2, 3, 4, 6, and 8 kHz for both air and

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bone conduction. Environmental noise assessment using portable Sound Level Meter standard was done at different departments and at different points of exposures during the working shift and two readings (minimum and maximum) were obtained at each site to find out the exposure levels of the solvents, Environmental monitoring of organic solvent levels at different work departments was obtained from the environmental records of the factory maintained by Egyptian National Institute of Occupational Safety and Health (Egyptian NIOSH) at the same year of the study. There was a highly statistically significant difference between the studied groups as regards hearing impairment $p < .001$ with group two having higher prevalence of sensory neural hearing impairment. They however recommended that in the case of combined exposure, noise and solvent levels should be lowered than the permissible limits recommended for either alone.

On the contrary, in the analyzes of auditory changes from combined exposure to noise and organic solvents through a pilot study in the furniture industry sector, Lopes et al (2013) performed audiological tests comprising pure tone audiometry and DPOAE on 44 workers belonging to four different sectors in the furniture industry who were exposed to either noise or the compositions of both noise and solvents. Their levels of exposure to toluene, xylene and ethyl benzene were determined and as well as levels of noise exposure were evaluated. The results showed that the combined exposure to noise and solvent, the exposure to high levels of noise alone were found not to have any association effect on hearing with reasons being that most of the workers assessed are young and did not show signs of hearing loss as well as their using of personal protective devices. Also the small sample size in the study was a major reason in the study. The authors concluded that broader samples should be taken into consideration to better characterize the difficulty of finding cause and effect relationship in the analysis of combined exposure to noise and ototoxic substance.

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2.5 HEARING LOSS DUE TO EXPOSURE SOLVENT ALONE IN PAINTS AND AUTOMOBILE GARAGES

Many studies have been done in many occupational settings on hearing loss as a result of exposure to noise and chemical solvents. The paint and automobile garages has not been left out as well. Early studies in the paint occupational setting can be referenced to Morata et al. in 1993. These authors in an investigation observed workers in the paint manufacturing industry showed that, occupational exposure to a solvent mixture containing mainly toluene, xylene, methyl ethyl ketone, and methyl isobutyl ketone increases the probability of hearing loss. These workers worked included placing cans on conveyor belts, controlling their filling, and closing and labeling them. These workers, who were exposed to a mixture of solvents but not noise, were compared with the printing industry that were both exposed to noise and solvents. Interviews, noise measurement and pure tone audiometry were done to assess the hearing status of the workers.it was found out that these paint workers who were labeled as solvent mixture group had five times greater (95% CI 1.4-17.5) for having hearing loss.

In a population of 117 workers in a paint and lacquer factory who were mainly exposed to a mixture of xylenes and ethyl acetate, Sliwinska-Kowalska et al., (2000) observed hearing loss among exposure group and two non-exposed control groups; noise as a control group, and additionally, another group of workers exposed neither to noise nor to solvents in their occupational setting .Results showed that a high percentage (30%) of hearing loss was found among exposed workers, in comparison to non-exposed workers which showed 6% and 20% only for the control group. Thus the group of workers exposed to xylene and ethyl acetate had worse hearing thresholds than the non-exposed workers. Their study emphasis the higher

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relative risk value for hearing loss in workers exposed to solvents in comparison to workers exposed only to noise.

The effect of solvent alone exposure on the effect of the peripheral auditory system has been severally been observed in the paint industry, however very few studies have observed its effect on the central auditory system. Fuente, McPherson, and Hickson, (2013) observed seventy-two non exposed workers who were non-academic personnel from a university and 72 solvent-exposed workers in two paint making industry whose job categories included maintenance engineers, production supervisors, machine operators, quality control employers, helpers, mixers, and hazardous waste handlers. Interviews, pure-tone audiometry (PTA), transient evoked otoacoustic emissions (TEOAE), Random Gap Detection (RGD) and Hearing-in-Noise Test (HINT) were done for all participants. One model for each auditory outcome (PTA, TEOAE, RGD and HINT) was independently constructed. For all of the models solvent exposure was significantly associated with the auditory outcome. The authors concluded that the sole use of pure-tone audiometry is not sufficient to monitor and/or assess hearing among solvent-exposed workers.

2.5 SYNERGETIC EFFECT OF NOISE AND SOLVENTS ON HEARING IN PAINT INDUSTRY AND AUTOMOBILE GARAGES

In a case study, Polizzi et al (2003) found a an unexpected pattern of hearing loss of a painter, who had a maximum loss in the low and mid-frequencies as a result of exposure to noise and a mixture of organic solvents. The authors implied that this pattern may be induced by a possible synergistic effect of noise exposure combined with solvents. Their findings however cannot be generalized for other workers because of the involvement of just one participant.

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With the limited studies done in the paint industry, there seems to appear a study investigating automobile garages and paint industry in combination. Mohammadi, Labbafinejad, and Attarchi (2010) in a cross section study of 411 workers of a large automobile plant showed that combined exposure to mixed organic solvents and occupational noise can exacerbate hearing loss in workers even at permissible level. Workers were group into three groups; noise exposed group (assembly workers), exposure to a mixture of organic solvents at a permissible level group (new paint shop workers) and exposure to both noise and higher than permissible levels of organic solvents group (old paint shop workers). Noise and chemical exposure survey were made. Pure tone audiometry was performed at 0.5 kHz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, and 8 kHz by both air and bone conduction.

The groups were compared in terms of low-frequency hearing loss (model 1; average hearing threshold >25 dB at 0.5 kHz, 1 kHz, and 2 kHz) and high-frequency hearing loss (model 2; average hearing threshold >25 dB at 3 kHz, 4 kHz, 6 kHz, and 8 kHz). It was found out that high-frequency hearing loss was more common in workers exposed to a combination of noise and mixed organic solvents even at permissible levels than in workers exposed to noise alone even after correction for confounding variables such as age, work experience and smoking.

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CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This Chapter presents the methodology of the study which includes the study design, study population and study sites. Further the chapter presents the study procedure of the study.

3.2 STUDY DESIGN

This is a cross-sectional study of participants exposed to noise or in combination of noise and solvents (study groups) and subjects without solvent or noise exposure (control group). This design was chosen to assess the difference in hearing among workers exposed to chemicals and noise and those not exposed at all in the same environment. Participants were divided or categorized into three groups according to their exposure to noise and solvent at the work place. The three groups namely; exposed to noise and chemical group (NCEG), noise exposed only group (NEG) and control group that is not exposed to noise or organic solvents. The control group for the paint company was all administrative personnel's whiles the control group for the auto mobile sprayers were those who were not exposed to the paints or solvents (chemicals). It was the plan of the researcher to include chemical exposed only group but this group of workers were not available to the various sites visited. The three groups were adjusted with their age. Comparisons for hearing ability were made between the four groups to establish the observational aspect of the study.

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3.3 STUDY SITES

The study was carried out in a paint industry (Bamson Industry limited) and five automobile spraying garages within the vicinity of Mataheko in Accra, the capital.

3.4 STUDY POPULATION

The study population included all workers in the various sites who consented to the study. Demographically, the population consisted of 115 participants (106 males and 9 females) aged between 20-57 years. Details of the demographics are presented in Table 4.1.

In the paint company, participants included workers who worked in the production, welding, spraying and administrative departments for at least six (6) months. Workers were selected from the administrative department to serve as an unexposed control group, since they were not occupationally exposed to any known or suspected ototoxic chemicals. These workers were mainly involved in office works. Sound measurement in this department showed that noise levels were in ranges (below 85dBA) and chemical survey indicated that there was no use of chemicals. The welding department whose activities included hammering of metals from cars and reshaping those using tools that emits high noise served as the noise exposure group. Again sound measurement in this department showed noise levels ranges between 90dBA and 92dBA exceeding 85dBA.The production and the spraying department served as the solvent and noise exposed group. Their working activity included manufacturing of latex paints and the use of paints, lacquers and thinners in the spraying of cars respectively. These two departments as well emit high noise from their machines and noise measurement showed ranges above 85dBA. After screening for exclusion criteria and inclusion criteria, 38 workers from these various departments

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entered the study and seven were excluded due to either perforation of the tympanic membrane or there was a case of impacted wax. All participants' were twenty-nine (29) men and nine (9) women and worked eight hours a day.

In the automobile garages, participants included workers who worked in the spraying, welding and mechanic departments who had worked for at least six (6) months. Workers were selected from the mechanic department to serve as unexposed control groups, since they were not occupationally exposed to any known or suspected chemicals that are ototoxic. These workers were mainly involved in the fixing of car parts which does not generate any noise or does not use chemical. Sound measurement in this department showed that noise levels were in ranges between 60 dBA and 75 dBA (below 85dBA) and chemical survey indicated that there was no use of chemicals that was ototoxic. The welding department whose activities included hammering of metals from cars and reshaping those using tools that emits high noise served as the noise exposure group. Again sound measurement in this department showed noise levels ranging between 90 dBA to 91 dBA (above 85dBA).

The spraying department served as the solvent and noise exposed group. Their working activity included the use of paints, lacquers and thinners in the spraying of cars respectively. This department emits high noise from their machines and noise measurement showed ranges above 85dBA. All these workers worked eight hours per day. Among the eighty five (85) participants who consented to participate, eight (8) workers were excluded according to exclusion and inclusion criteria. All participants voluntarily involved themselves in this study and were given informed consent form (appendix IV and appendix V) to sign.

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3.5 SAMPLE SIZE AND SAMPLE TECHNIQUE

The convenience and purposive sampling techniques were used in conjunction to randomly select available participants who met requirements of the inclusion criteria. These techniques allow for choosing readily available participants as well as handpicking of participants into the exposure groups and non-exposure groups. Participants were picked according to the inclusion and exclusion criteria. Based on these reasons, a sample size of 115 participants was chosen for the study.

3.6 INCLUSION AND EXCLUSION CRITERIA

3.6.1 Exclusion Criteria

Individuals in the study sites who do not consent to participation as well as those who had the under-listed audiological and medical histories were excluded from the study.

- History of consumption of ototoxic drugs in past three months
- History of ear surgeries performed in the past.
- Histories of recent and past ear infections in the in the nose, throat or ear.
- History of workers with otoscopy evidence of tympanic membrane perforation, audiometric evidence of conductive & mixed hearing loss, and with ear disease or discharge.
- History of workers who previously worked in noisy occupations

3.6.2 Inclusion Criteria

All workers in the study who consented to participate in the study.

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3.7 INSTRUMENTATION AND MATERIALS

3.7.1 Otoscopy

Cefixoral CE 11 clinical otoscope was used to inspect for cerumen and foreign materials before testing to establish clean ear canal.

3.7.2 Immittance Device Tympanometry

The immitance device is a device that picks the pressure of the ear. A schematic of the immitance device used in this study is shown in Fig. 3.1.

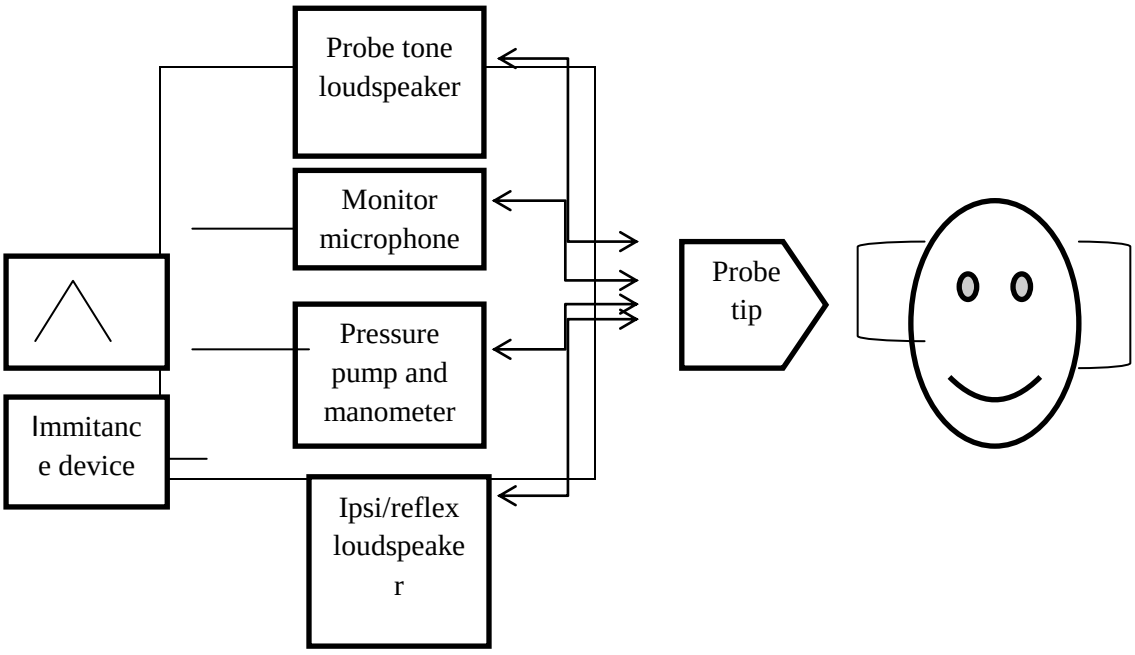


Figure 3.1 Block Diagram of the Immittance Device

Tympanometry was used to rule out middle ear pathology and this was done using the Interacoustics IMP440 Titan hand held middle ear analyzer employing a 226 Hz probe tone. This device measures the peak compliance and peak pressure of the ear at a frequency of 226Hz.A probe tip which includes four tubes is inserted into the ear canal. One tube is connected to a receiver loudspeaker to deliver a 226Hz tone into the ear canal. The second tube is connected to

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a microphone used to monitor the sound in the ear while the third is connected to pressure pump and meter and a receiver for testing acoustic reflex respectively. These tubes measure the acoustic admittance of the ear and displayed normally as plotted as graph.

3.7.3 Sound Level Meter

The radio shack realistic 33-2050 sound level meter (type 2) was used. The microphone detects the small air pressure variations associated with sound and changes them into electrical signals. These signals are then processed by the electronic circuitry of the instrument. The readout displays the sound level in decibels. The SLM takes the sound pressure level at one instant in a particular location.

3.7.4 Pure Tone - Computer-Based Audiometer (Kudu Wave 5000)

KUDU Wave 5000 is type 2 computer-based clinical audiometer (Electrotechnical Commission 2012), equipped with software control and connected to a Notebook computer (Acer Travel mate 2492 running Windows XP), as shown schematically in Fig. 3.2. The validity of this computer-based diagnostic air and forehead bone conduction audiometer has been investigated by comparing it with a conventional industry standard audiometer and it was found to correspond to that of the industry standard audiometer within typical test-retest reliability limits (Swanepoel and Biagio, 2011). This equipment has been shown to provide possible sufficient earphone attenuation and real-time monitoring of environmental noise without sound treated room (Swanepoel, Maclennan-Smith & Hall, 2013). It has a custom inserted foam ear-tips and earphones covered by circumaural ear cups to provide additional attenuation. There are also microphones on the outside and inside of the circumaural ear cup to monitor environmental noise and determine the amount of acoustic attenuation. These features allow for assessment in

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suboptimal environments outside a soundproof booth. The audiometer hardware is contained within circumaural earcups that plug into the Netbook via an USB cable. At the centre of the circumaural headband is a standard adjustable spring headband with a bone oscillator that measures the bone conduction audiometry. An electronic patient response button is also connected to the device.

All equipment was calibrated at the time of data collection. The computerized KUDU wave 5000 audiometer was calibrated on the 29th of August, 2012 by GeoAxon Holdings (Pty) Ltd. Further, daily biological calibration checks were also performed before the testing.

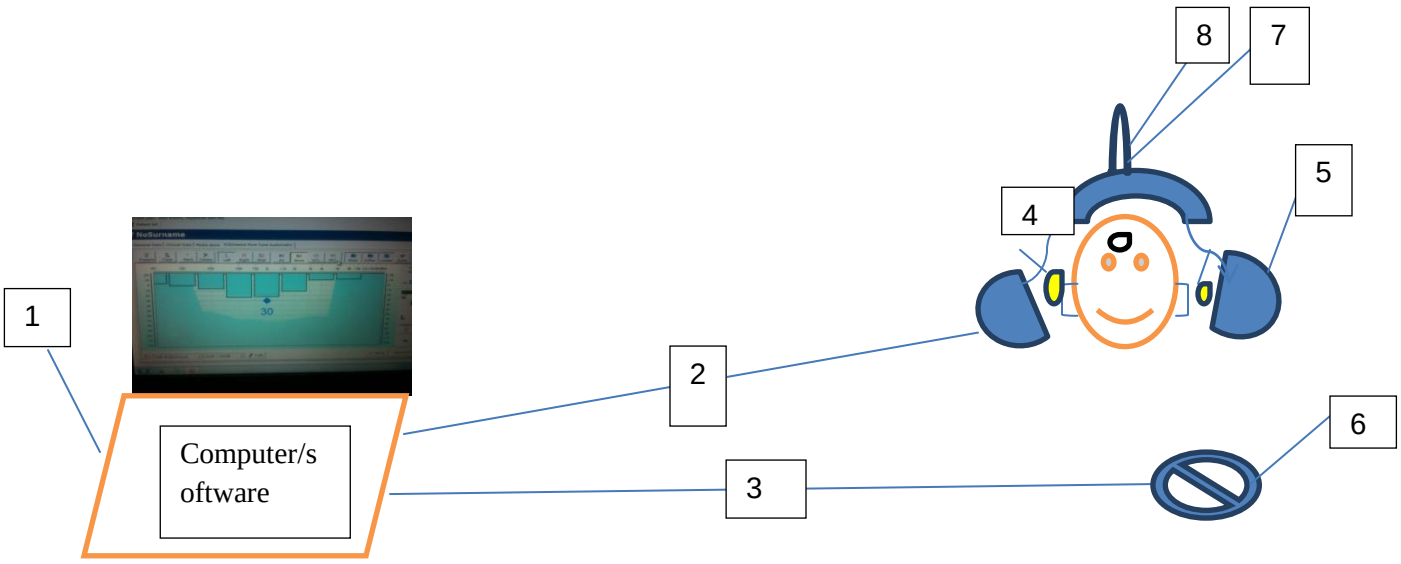


Fig. 3.2 Block Diagram of a Kudu Wave 5000 Computerized Audiometer

1. A netbook computer with software for pure tone audiometry 2. Wire to connect to circumaural head phone. 3. Wire to connect to response button.4. Insert form tips 5.circumaural ear cups 6.response buttons. 7. B-71 Bone oscillator.8.Spring headband.

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3.8 EXPERIMENTAL AND DATA COLLECTION PROCEDURE

The experimental data was collected through interviews, physical examination, otoscopy, tympanometry, chemical survey, noise exposure survey and pure tone audiometry.

3.8.1 Interviews

The questionnaire (extracted from Noisechem questionnaire, Morata and Little, 2002, and described in Appendix VI) addressed participants' demographic data including name, gender and age, ear history and medical conditions that may be associated with the onset of auditory dysfunction, the use of ototoxic drugs; occupational history (such as, previous jobs exposed to noise, use of solvents, use of hearing and respiratory protection at work, duration of working, and department of the worker). The use of protective device and ear plugs was described by the use of three point scale; never, always, sometimes. The age and duration were however recorded as responded by participants. The questionnaire was utilized to select only participants into the inclusion criteria, and to explore covariates such as age, gender, and previous noise exposure for further inclusion in multivariate analyses.

3.8.2 Physical Examination and Immittance Audiometry

Otoscopy was done physically to rule out middle ear infection, impacted wax and ear perforation. Tympanometry was performed using the Interacoustic Titan IMP440 Middle-Ear Analyzer. A stimulus tone of 226 Hz protocol was used. The traces were compared to clinical protocol norms used by Korle Bu Teaching Hospital Hearing Assessment Center (Appendix VII) to determine types of tympanograms and to rule out middle ear pathology. Type A tympanograms, consistent with normal middle ear pressure and compliance, were defined by ear

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canal volume of 0.2- 2.0ml, peak pressure between -150 and +100 daPa, and peak compliance of 0.2-2.0ml.

3.8.3 Solvent Exposure Survey and Assessment

Due to technical difficulties, assessment of the various air concentrations of the chemicals found in the various study sites were not done physically. However, knowledge of the chemicals was done mostly through workplace narratives. This was verified by other sources which included the chemical purchasing records. A participant was considered as chemical exposed if he/she worked directly with that particular chemical.

In particular, the ototoxic chemicals found in both the paint company and automobile spraying garages were mostly thinners, lacquers and paints. The exact concentration inhaled by the workers could not be determined as there was no retrospective data of chemical exposure survey in both sites. Thus, it was difficult to conclude that these chemicals contained specific organic solvents Solvent exposure dose of every worker could also not be determined and calculated due to lack of appropriate equipment.

3.8.4 Noise Exposure Survey and Assessment

The background noise of the assessment room was measured and found to be around 30dB.This served as a quiet environment for assessment. The background noise levels in the assessment room was monitored and checked twice to ascertain that it remained the same throughout the experiment. Environmental noise surveys were carried out at the different departments during the working hours and three measurement readings were taken to obtained average noise level using the sound level meter (SLM). The results of these surveys are presented in Table 4.4.

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3.8.5 Pure Tone Audiometry

Pure-tone thresholds in dB HL were ascertained using the modified Hughson-Westlake method (up 5, down 10). A calibrated computerized KUDU wave 5000 audiometer was used to generate a pure tone that was presented to each ear via insert earphones for standard pure-tone audiometry. Each participant's air conduction thresholds was measured in 5 dB steps at 250Hz, 500Hz, 1kHz, 2kHz, 3kHz, 4kHz, 6kKz, 8kHz in each ear. A pulsed tone was used since is easier to distinguish without adversely affecting the results, particularly for tinnitus sufferer. Air conduction masking using a plateau method was applied to establish true audiometric thresholds when the air conduction thresholds of the test ear and of the non-test ear differed by at least the minimum inter-aural attenuation value for the test frequency. Forehead placement bone-conduction audiometry was conducted with both ears occluded by the deep insertion of the earphones.

Bone conduction thresholds were measured from 500 kHz- 4 kHz only, where the air conduction threshold was 25 dB HL or greater. An audiogram was classified as normal if none of the single hearing thresholds exceeded hearing loss of 25 dB for either ear. The bilateral threshold of the frequency ranges of 500 kHz to 2 kHz was categorized as low frequency loss whiles bilateral threshold average of the frequencies 3 kHz to 8 kHz was categorized as high frequency loss.

3.9 DATA ANALYSIS

A threshold above 25dB was defined for hearing loss. The binaural average of pure-tone thresholds (PTA) was expressed by the following equation: [(right ear threshold at 500 + 1000 + 2000 + 3000 + 4000 + 6000 + 8000 Hz) + (left ear threshold at 500 + 1000 + 2000 + 3000 + 4000 + 6000 + 8000 Hz)]/14]. The binaural average for the high frequency was expressed as:

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[(right ear threshold at 3000 + 4000 + 6000 + 8000 Hz) + (left ear threshold at 3000 + 4000 + 6000 + 8000 Hz)]/8] whiles the low frequency hearing loss was expressed as [(right ear threshold at 500 + 1000 + 2000 Hz) + (left ear threshold at 500 + 1000 + 2000 Hz)]/6.

ANOVA was used to compare age and working experience variables among the groups. Logistic regression analysis was used to find the odd ratio between exposure to noise and organic solvents and hearing loss with the results of statistical analysis expressed as odds ratio (OR) with 95 % confidence intervals (95 % CI). The independent *t*-test was used to find the difference in characteristics and degree of hearing loss. P values less than 0.05 were weighed statistically significant. Data compilation and results were all analyzed using the SPSS statistical package version 16. Descriptive statistics were used to describe the percentage of hearing of loss.

3.10 ETHICS

Permission to carry out the research was obtained from the Ethics and Protocol Review Committee of University of Ghana School of Biomedical and Allied Health Sciences to the various industries. (Appendix II). Informed written consents were obtained from the workers prior to audiological assessment. (Appendix VI). Objectives and testing procedure of the study were made available for participants. (Appendix V). Workers confidentiality was maintained in accordance with the conditions of ethical approval from the above-named ethics committee and privacy was ensured by keeping the identity of the participants anonymous.

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CHAPTER FOUR

RESULTS

4.1 INTRODUCTION

The study aimed at investigating the prevalence of occupational hearing loss among workers exposed to organic solvents and noise in the paint industry, and to compare prevalence and characteristics of hearing loss among these workers. The details of the results include demographic characteristics of the population, surveys of the work sites pertaining to noise and solvent exposures present at the working sites as well as exposure classification criteria, and the hearing evaluation status pertaining to the participating groups.

4.2 CHARACTERISTICS OF THE POPULATION

A total of 115 participated in the study. The demographic characteristics of the population of 115 participants are presented in Table 4.1. The average age of all workers was 33.49 ± 8.76 years (range: 20 to 57 years).The average years of work experience was 8.97 ± 6.89years (range: 1 to 31 years). None of the workers from the various sites smoked and none used personal protective devices such as ear plugs during working hours.

The solvents and noise exposure group recorded the highest number of participants followed by the unexposed group and lastly the noise alone exposure group. One-way ANOVAs were conducted to measure group differences in mean age, years of working. The results reveal no significant effects of group on age, $F(2, 112) = 0.926$, $p > 0.05$; and duration of working $F(2,112) = 0.475$, $p > 0.05$.

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Table 4.1: Demographic characteristics of population

Demographic variable	**Groups**			**Statistics**
	Unexposed	Solvents and noise	Noise-only	*p*- value
		Age (yrs.)		
20- 25	8	5	2	
26 - 30	14	21	8	
31- 35	3	8	9	
36-40	6	1	4	
41- 45	1	7	5	
46 - 50	3	1	3	
51 -55	2	2	1	
56 - 60	0	1	0	
∑	37	46	32	
Mean	32.46 ± 9.18	33.41 ± 8.93	34.71 ± 8.09	0.339
		Years of working experience		
Mean	8.30 ± 5.59	8.93 ± 7.80	9.74 ± 6.66	0.623
		Use of personal protective device		
Mean	0.00	0.00	0.00	
		Ototoxic medication		
Mean	0.00	0.00	0.00	
		Tympanogram		
Mean	Type A, N=37	Type A, N=46	Type A, N=32	

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This is suggestive that the groups did not differ in age and duration of working. All the three groups presented with type A tympanogram status which indicated a normal middle ear function.

4.3 EXPOSURE CRITERIA AT WORK SITES

The workers were grouped into either exposure or non-exposure group by classifying them according to the criteria described in Table 4.2.

Table 4.2: Criteria for determining exposure status

Exposure status	Exposure Class	Identification of job	Exposure level
Non exposed to hazardous noise	0	noiseless job, such as office work	Average of 40dBA
Exposed to hazardous noise	1	jobs with a mild noise level, such as assembling, working parts, and repairing engines	Average of 72dBA
	2	Involves jobs with high level of noise such as machine use for scrapping the cars	Average of 92dBA
Chemical/solvent present			
Minimal chemical solvent exposure	0	Jobs in which solvents or chemicals are rarely used such as the office work and repairing engines, working parts.	none
Regular exposure	1	Jobs which involve seldom use of solvents or chemical	paints
	2	Jobs which involve the regular and frequency use of solvents/chemicals	Paints/lacquers and thinners

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Noise measurements recorded with the sound level meter during working periods at the study sites were made three times on three different days and averaged. The survey of solvents or chemical used at the various sites were recorded and categorized. The average of highest sound level measurement was 92dBA and was most prevalent among the spraying departments of the various sites. Paints were the most utilized chemicals at the work sites, while thinners and lacquers were mostly used at the spraying garages.

4.4 PREVALENCE OF HEARING LOSS AMONG THE GROUPS

Table 4.3 depicts the prevalence of normal hearing and hearing loss among the groups. In assessing the hearing status of the workers, a hearing loss threshold above 25dB was assumed for all frequencies in both ears. Out of 115 participants, 15 (13.0%) of them presented with hearing loss. A cross-tabulation analysis revealed that the hearing loss was most prevalent (53.3%) among the solvent and noise exposure group. The noise-only and non-exposed groups recorded lower prevalence of 40% and 7% respectively.

Table 4.3: Percentages of hearing loss among groups

Hearing status	Exposure groups						**Total**
	No exposure		Noise-only		Solvents and chemicals		
	No.	Percent	No.	Percent	No.	Percent	
Normal hearing	36	36.0	26	26.0	38	38.0	100
Hearing loss	1	7.0	6	40.0	8	53.3	15
∑ (total)	37	32.2	32	27.8	46	40.0	115

Out of fifteen (15) participants, whom had hearing loss, the group exposed to both solvent and noise recorded the highest prevalence of 53 % with the non-exposure group having the least prevalence of 7%.

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4.4.1 Hearing loss differences among groups.

The mean and standard deviation of the groups were described using the bilateral pure tone average of all the frequencies. With the help of ANOVA, the inter-group prevalence of hearing loss was compared. Table 4.3 depicts the descriptive differences among the groups. ANOVA analysis however showed a significant difference (p=0.045 <0.05; $F_{(2,112)}$= 3.197, p < $n.s$) of prevalence hearing loss difference among the groups (Table 4.4).

Table 4.4 Descriptive differences among Groups

	Non exposed group (N=37	Solvent and noise exposed group (N=46)	Noise exposed only group (N=32)
mean	17.16	22.20	22.67
standard deviation	3.10	12.65	12.10

Table 4.5 Group differences of prevalence of hearing loss using ANOVA

ANOVA

Hearing loss	Sum of squares ($\left(\sum x^2\right)$	*df*	Mean square ($\bar{x}^2$)	*F*	*p*-value
Between Groups	689.721	2	344.861	3.197	.045
Within Groups	12082.053	112	107.875	-	-
Total ∑	12771.774	114	-	-	-

4.5 PREVALENCE OF HEARING LOSS USING ODD RATIO

Using simple logistic regression analysis, the independent variable groups (non-exposed, noise only, solvent and noise) predict the odds of the dependent hearing loss variable (yes or no). No significant prevalence difference (p > 0.05*)* was found between the noise-only group (n=32) and the solvent and noise only (n=46) in comparison with the control (n=37) group. Comparatively,

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the noise-exposed, and solvents and noise exposed groups had 0.132 (95% *CI*=0.340 to 3.532) and 1.096 (95% *CI*=0.016 to 1.108) times higher odds times than the unexposed group in respect of prevalence of hearing loss (Table 4.4).

Table 4.6: Prevalence of hearing loss among groups using odd ratio

Groups	B	SE	Significance	*p*-value	Odd Ratio	95% Cl
Non-exposed	-	-	-	-	-	-
Noise only	-2.025	1.086	0.062	0.062	0.132	0.016-1.108
Solvent and noise	0.092	0.597	0.878	0.878	1.096	0.340-3.532

A graphical illustration of the odd ratio variation among the groups is shown in Figure 4.1.

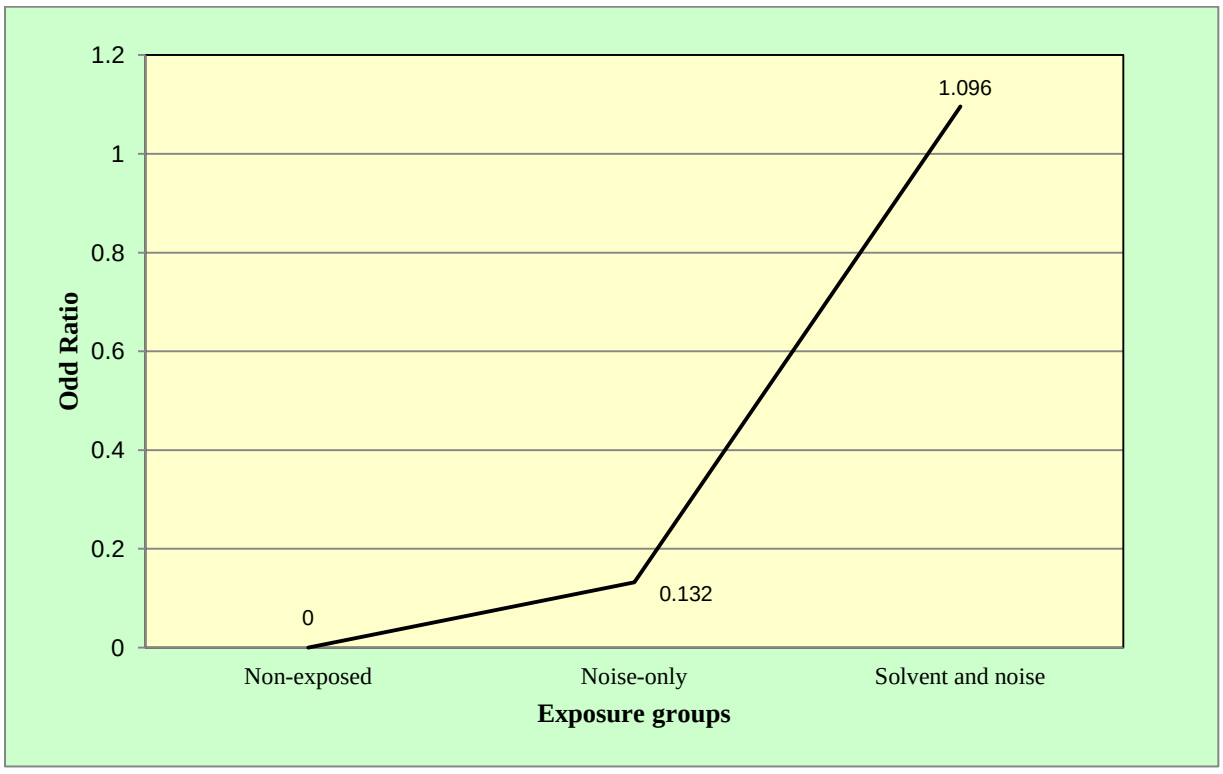


Fig 4.1: Odd ratio of hearing loss among groups

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4.6 HEARING LOSS AMONG GROUPS OF HIGH AND LOW FREQUENCY AVERAGE

Using the independent *t*-test, differences were made in the characteristics of hearing loss among the groups. Hearing loss at low and high bilateral frequencies averages were both compared.

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Table 4.7 Inter-group comparison of hearing loss

Frequency category	Mean	St. dev.	Frequency	Test of significance
Low frequency	1.13	0.21	5	t= 2.98, df=114
				p =0.03, thus p <0.05 (2- tailed)
High frequency	1.04	0.34	15	

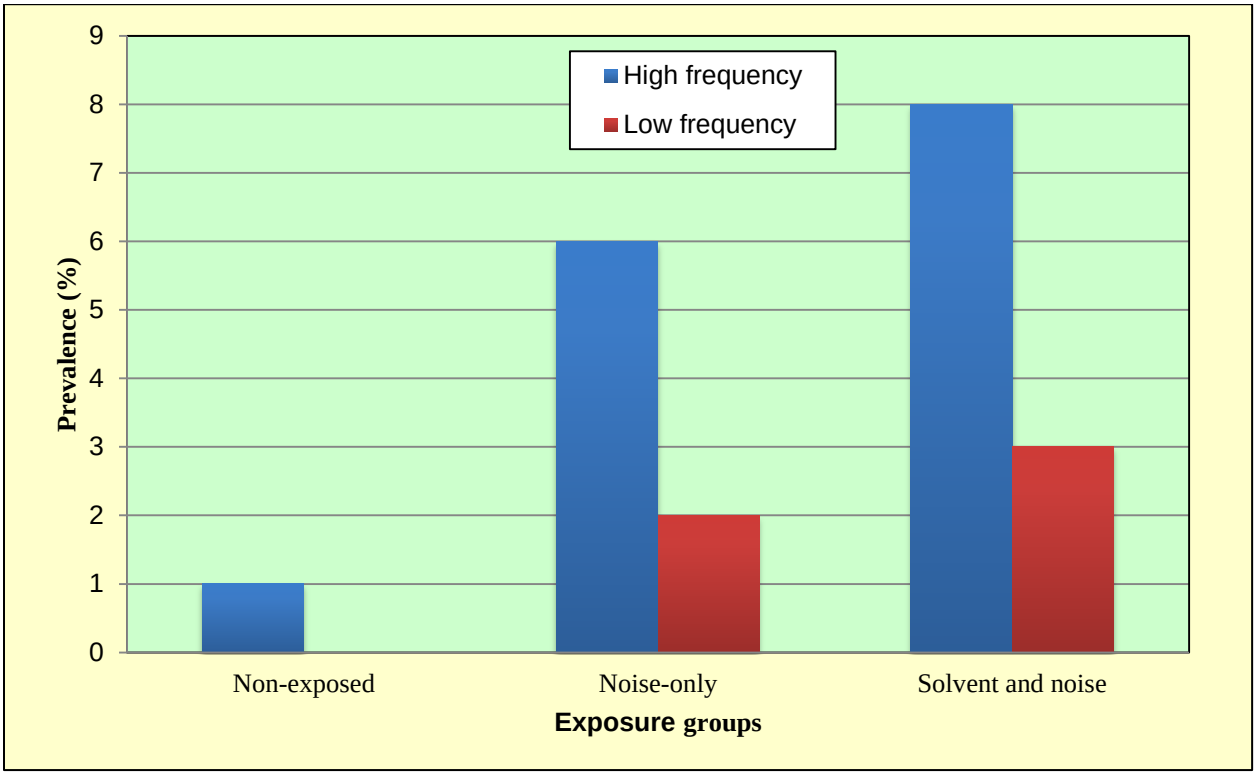


Figure 4.2: Prevalence of high and low frequency hearing loss among groups

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The results of Table 4.6 established a significant difference (p=0.03 <0.05) among high and low frequency hearing loss. Higher occurrences were associated with high frequencies and vice-versa The solvent and noise exposure group recorded the highest occurrences of high and low frequency hearing loss with prevalence of 8% and 3% respectively. The noise-only group presented with prevalence values of 6% and 2% for high and low frequency hearing loss. However the least was recorded for the non-exposed group with a prevalence of 1% for high frequency hearing loss and none for low frequency hearing loss.

In finding the differences of binaural average of high and low frequency among the groups, figure 4.3 depicts the mean binaural averages of groups. The solvent and noise exposure recorded the highest mean in low and high frequency category recording 20.42 and 30.64 respectively. The noise only group followed with 19.30 and 30.13 whiles the non-exposure group recorded the least with 13.82 and 19.05 respectively.

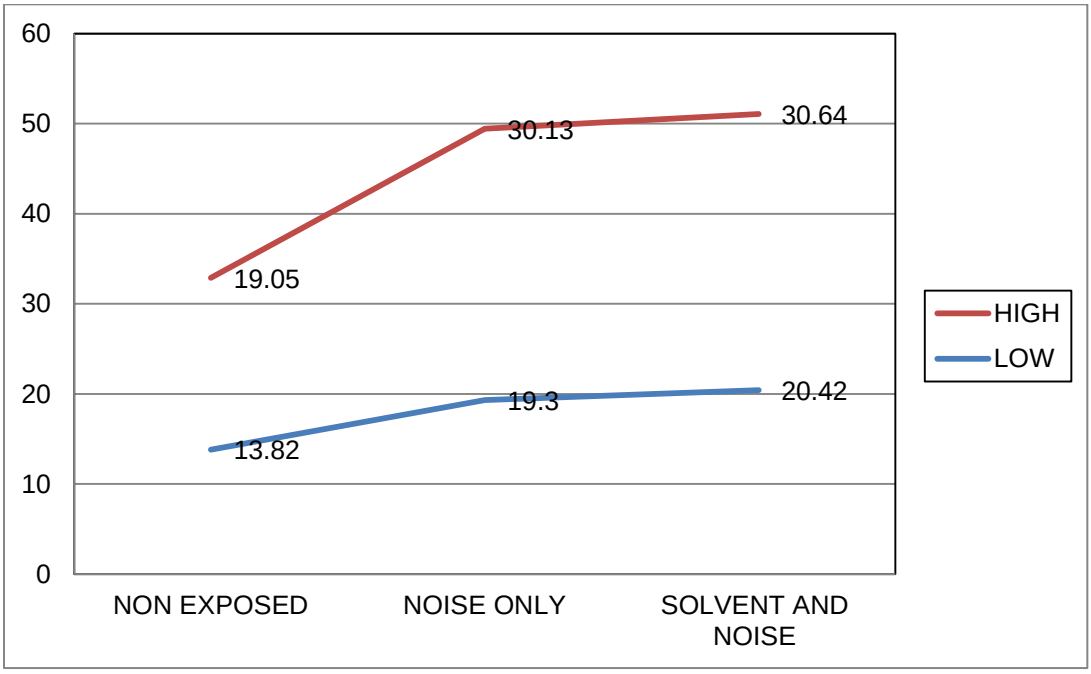


Fig. 4.3: Mean binaural average of high and low frequency among groups

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Confirming the differences of high and low frequency averages, ANOVA was used to find the differences among the groups. The results of Table 4.7 established a significant difference (p=0.02 <0.05) among groups for the high frequency average.

Table 4.8: Differences of high frequency average among groups

ANOVA					
Hearing loss	Sum of squares ($\left(\sum x^2\right)$	*df*	Mean square ($\bar{x}^2$)	*F*	*p*-value
Between Groups	3254.77	2	1627.39	6.780	.002
Within Groups	26882.49	112	240.02	-	-
Total $\sum$	30137.27	114	-	-	-

n.s means not significant difference

Again, table 4.8 depicts a significant difference (p=0.026 <0.05) among groups for the low frequency average. ANOVA analysis however showed a significant difference (p=0.026 <0.05; $F_{(2,112)}$= 3.770, $p < n.s$) of differences of low frequency difference among the groups (Table 4.9).

Table 4.9: Differences of low frequency average among groups

ANOVA					
Hearing loss	Sum of squares ($\left(\sum x^2\right)$	*df*	Mean square ($\bar{x}^2$)	*F*	*p*-value
Between Groups	969.80	2	484.900	3.770	0.026
Within Groups	14405.920	112	128.624	-	-
Total $\sum$	15375.72	114	-	-	-

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CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

Occupational hearing loss has been one major problem confronting many industrialized countries and has become a major problem confronting developing countries. In the past, occupational hearing loss was solely attributed to sources emitting high acoustic intensities. However, other sources such as chemicals have been identified in recent times. In this study, 115 workers were audiologically investigated and evaluated via pure tone audiometry and tympanometry to assess the prevalence of occupational hearing loss. Broadly, the specific aim of the study was to investigate the prevalence of occupational hearing loss among workers exposed to industrial chemicals and noise in a paint company and among car sprayers in five garages, and compare the characteristics and degree of hearing loss between the study groups.

5.2 RESEARCH QUESTION AND HYPOTHESES

5.2.1 Research Question: The research question stated was that;

In comparison to workers not exposed to chemical solvents and noise, do those who are exposed to both solvent and noise have higher odds of having hearing loss than noise exposed only? Results from the odd ratio analysis of group revealed that solvent and noise exposed group had an increased odd ratio of 1.096 of having hearing loss than the noise exposed only group with 0.036 odd ratios when compared to the control group. This finding suggests that occupational exposure to these agents has effects on the auditory system. In particular, this could result in the likelihood of ototoxicity and ototraumatic mutual or reciprocal action between exposure to noise

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and chemical solvents. This result is consistent with other findings with respect to combined exposure of solvents and noise as compared to noise and solvent alone (Morata et al.,1993; Sliwinska-Kowalska et al.).

Similarly, Morata et al., (1993) found odd ratios of 4.1, 5.0 and 11.0 for noise-only, solvent-alone, and noise in combination with solvent groups respectively. Sliwinska-Kowalska et al., (2004) confirmed this in a study on dockyard workers and established that the odds ratio for hearing loss increased by 5 in the noise and solvent group, and 3 in the noise-only group. Most of these have focused on the relative risk between other variable such as age, solvent exposure index, noise exposure index, and duration of exposure. Risk factors have also been used to find the odd ratio of having hearing loss among groups. However this study did not explore the use of these variables to find the odd ratio of hearing loss which could have led to the insignificant odd ratio among the group although most of the variables were used to rule out inclusion and exclusion criteria.

5.2.2 Hypothesis

Hypothesis 1: Solvent and noise exposure group will have a higher prevalence of hearing loss than the noise only and control groups.

In order to test the difference of prevalence of hearing loss differences among the groups, ANOVA was used to test this alternate hypothesis. However this hypothesis was refuted at a significance level of 0.05 suggesting that chemical solvent and noise exposure group did not have higher prevalence of hearing loss than the noise only and control groups. This is at variance with other studies on the same subject where large sample size was used. The reason for this difference with other studies is not far-fetched. In the first place, the sample size used in the

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study is small hence the analysis could not reveal the expected outcome of the analysis. Lopes et al (2013) recently found out that the combined exposure to noise and solvent is not significantly associated with hearing mostly due to age, short duration of exposure of the participants, the small size and their personal protective devices. Higher prevalence of hearing loss due to exposure to noise and solvents had been reported with no statistical difference among groups. Also, Morata, et al (1997) had found no statistical interaction between toluene and noise in inducing hearing loss with workers who had , had a relatively short duration of noise exposure although they reported having 49% of workers having hearing loss.

However, looking at the data in percentage terms, it was observed that 53.3% prevalence of hearing loss in the group exposed to noise and chemical solvents was higher than those in the other groups (6.7% in the unexposed group, 40.0% in the noise-only). These study groups did not differ in age and work experience and hence their hearing loss can largely be attributed to exposure to noise and chemical solvents. The study surveyed the noise exposure of the workers and categorized them into the exposure class status. Most of the noise-only group was found in the "class 2" category with defined noise levels above 85 dB(A). However, according to Phillips et al. (2007), workers exposed to noise levels above 82 dB (A) are at risk for NIHL, and those exposed to levels above 90 dB (A) are at high risk Occupational noise above 85 dBA seems to pose effects on the auditory system with or without solvent exposure. Previous studies and research have confirmed these findings. In particular, with an average noise of 85dBA, Boateng and Amedofu (2004) found striking effects on the hearing capabilities of workers on industrial noise pollution and its effects on the hearing capabilities of workers with evidence of noise-induced hearing loss (NIHL).

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Exposure to solvents alone has been found to have an effect of reducing pure tone thresholds. This has been agreed on both animal and human findings. Sliwinska-Kowalska et al (2000) confirmed this in a study which reported 30% prevalence of hearing loss among solvents-exposed workers, and 6% and 20% respectively for noise-exposed and non-exposed groups. Chemical solvents can affect the sensory cells and peripheral nerve endings of the cochlea, and further have a retro cochlear power and affect the brain. The study however focused on the combined effects of exposure to solvents and noise on hearing.

Hypothesis 2: Prevalence of high frequency hearing loss will be higher than the prevalence of low frequency hearing loss among those with hearing loss

The results of this study showed that high frequency hearing loss was higher than low frequency hearing loss among those who presented with hearing loss with 95% confidence interval of 0.029 and 0.145. This hypothesis was supported at a significance level of p=0.05. The study recorded a prevalence of 5% for low frequency hearing loss and a higher prevalence of 15% for high frequency hearing loss. Again the mean binaural average of the high frequency was higher among the groups than the mean binaural average of the low frequency with the group exposed both to the solvent and noise recording the highest mean. These findings agree with previous studies by Fuente, McPherson and Hoodt (2012), Sliwińska-Kowalska et al. (2003), and Rabinowitz et al (2007) which found high frequency hearing loss in the frequencies of 2000Hz to 8000Hz on pure tone audiometry.

Mohammadi, Labbafinejad, and Attarchi (2010) also found out that high-frequency hearing loss was more prevalent in workers exposed to a combination of noise and mixed organic solvents

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even at permissible levels than in workers exposed to noise alone even after correction for confounding variables such as age, work experience and smoking. The comparison was made in terms of low-frequency hearing loss and high-frequency hearing loss. Thus, with this findings on low frequency and high frequency in this study and on previous studies, a wide range of pure tone audiometric frequencies are affected by solvent and noise exposure in the auditory system of man.

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CHAPTER SIX

CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

6.1 INTRODUCTION

This chapter summary all the findings and present the conclusion, recommendation as well as the limitations of the study.

6.2 CONCLUSIONS

Occupational hearing loss has been investigated in various setting and by different methods. This study aimed at investigating the prevalence of occupational hearing loss among workers exposed to industrial chemicals and noise in a paint company and among automobile sprayers and secondly comparing the characteristics and degree of hearing loss between the study groups. Based on these, the study specifically objected to the;

(1) determination of noise exposure levels of workers exposed to noise.

(2) survey the industrial chemicals used in the paint company and the automobile spraying garages.

(3) determination of characteristics of hearing loss among participants using pure tone audiometry.

One hundred and fifteen participants grouped in three underwent audiological evaluation on pure tone audiometry and their hearing status was compared and analyzed. The odd ratio and prevalence of the hearing status among the groups was determined and tested at significance level .

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The finding of the study includes;

- Group exposed to both solvent and noise had higher odds of having hearing loss than noise exposed only when compared to the control group although the magnitude was much smaller than from other studies.
- Solvent and noise exposure group had 53.3% higher prevalence of hearing loss than the noise only with 40% and control group with 6.7%.
- Prevalence of high frequency hearing loss was higher than the prevalence of low frequency hearing loss among those with hearing loss.

This finding implies that much attention should be paid to the presence of both noise and chemical solvents in the occupational setting as they have the potential of increasing hearing loss.

6.3 RECOMMENDATION

With these findings, workers should be enlightened on the use of protective devices during working hours and authorities at the work place should emphasis on its use. Secondly workers in these sectors should at least have their hearing checked annually. Thirdly, education of ototoxic chemicals and its effects should be provided for all workers to reduce occupational hearing loss. Finally, others wishing to pursue research in this area should control certain factors such as having a solvent exposed group only, the documentation and controlling for length of exposure as well as the measure of air concentration of solvents.

6.4 LIMITATION OF THE STUDY

Per the suggested guidelines for studying the combined effects of occupational exposure to noise and chemicals on hearing as presented by Morata and Little (2002), air sampling for chemicals

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should have been done in this study. Individual chemical exposure data was the major limitation in the characterization of the solvent and noise-exposed group. No airborne chemical concentrations were done in this study and none of the study sites had records of these. The study estimated the number of years of exposure to chemical by each worker in the present job category to determine the exposure history of participants. Hence calculations of working life exposure indexes were not obtained. The inadequacy of these data limits the results of this study, and the need to find the relations and association levels of solvent, noise exposure and auditory function.

Secondly, the use of pure tone audiometry as the only determinant of hearing loss is another limitation of the study. Other test battery could have increase the knowledge of the reseach. Thirdly, this study was a cross sectional study and as such no causal and effect relationship can be drawn. Although findings were drawn from the investigation, it cannot be infer that exposure to solvents and noise causes hearing loss. Finally, the inadequacy of equipment and resources for the use of different test batteries in the determination of hearing loss is another fall of this study. Different test batteries could have enhanced and critically capture various hearing loss in the study.

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APPENDIX 1 SAMPLE OF LETTER TO THE VARIOUS SITES

SCHOOL OF ALLIED HEALTH SCIENCES
COLLEGE OF HEALTH SCIENCES
UNIVERSITY OF GHANA
DEPARTMENT OF AUDIOLOGY

Phone: +233-0302-687974/5
Fax: +233-0302-688291
My Ref. No. SAHS/
Your Ref. No.

P O Box KB 143,
Korle Bu, Accra

Sep. 9, 2013

The Administration Manager
Bamson's Ghana Ltd
Accra

Dear Sir,

PERMISSION TO CARRY OUT MSc RESEARCH PROJECT AT BAMSON'S GHANA LTD.

Ms. Deborah Tetteh is a 2nd year MSc Audiology student in the Department of Audiology of the University of Ghana School of Allied Health Sciences (SAHS).

She is conducting her MSc research dissertation project in occupational chemical-induced hearing loss among workers exposed to organic solvents in Ghana under the supervision of Clinical Audiologists and Scientists/Lecturers of the School.

The Department would be most grateful if you could kindly grant her permission to carry out this important research project at your organization from September 2013-March 2014 for the common good of your institution and the University. Thank you

Yours faithfully,

Dr. S. ANIM-SAMPONG
(Academic Coordinator)
cc The Dean, SAHS

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APPENDIX II ETHICAL CLEARANCE LETTER

SCHOOL OF ALLIED HEALTH SCIENCES
COLLEGE OF HEALTH SCIENCES
UNIVERSITY OF GHANA
ACADEMIC AFFAIRS

Phone: +233-0302-687974/5
Fax: +233-0302-688291

My Ref. No. SAHS/ 10209645
Your Ref. No.

P. O .Box KB 143
Korle Bu
Accra
Ghana

12th May, 2014.

Ms. Deborah Tetteh,
Dept. of Audiology,
SAHS,
Korle Bu.

Dear Ms. Tetteh,

ETHICS CLEARANCE

Ethics Identification Number: SAHS – ET. /10209645/AA/3A/2013-2014.

Following a meeting of the Ethics and Protocol Review Committee of the School of Allied Health Sciences held on Monday 24th March, 2014, I write on behalf of the Committee to approve your research proposal as follows:

TITLE OF RESEARCH PROPOSAL: **"Occupational Hearing Loss among Workers Exposed to Organic Solvents and Noise: A Study in A Paint Industry and among Automobile Sprayers".**

This approval requires that you submit six-monthly review reports of the protocol to the Committee and a final full review to the Committee on completion of the research. The Committee may observe the procedures and records of the research during and after implementation.

Please note that any significant modification of the research must be submitted to the Committee for review and approval before its implementation.

You are required to report all serious adverse events related to this research to the Committee within seven (7) days verbally and fourteen (14) days in writing.

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As part of the review process, it is the Committee's duty to review the ethical aspects of any manuscript that may be produced from this research. You will therefore, be required to furnish the Committee with any manuscript for publication.

Please always quote the ethical identification number in all future correspondence in relation to this protocol.

Thank you.

Yours sincerely,

Dr. Michael Mark Addae
(Chairman, Ethics and Protocol Review Committee)

cc Dean
Co-ordinator/HoD, Dept. of Audiology
Senior Assistant Registrar

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APPENDIX I11 LETTER FOR EQUIPMENT

Kaneshie –Accra

24th February, 2014

Department of Audiology

School of Allied health,

University of Ghana

APPLICATION FOR RELEASE OF EQUIPMENT

Dear Sir,

I Deborah Tetteh, second year Msc. Audiology student kindly need the following equipment to carry out my project.

1. Kudu wave 5000 (computerized audiometer)

2. Hand held Tympanometry

It will be my responsibility to handle them well. I hope my humble request will be granted. Thank u.

Yours sincerely,

Deborah Tetteh

University of Ghana http://ugspace.ug.edu.gh

APPENDIX IV

PARTIPANTS INFORMATION FORM

School of Allied Health Sciences
College of Health Sciences
University of Ghana
Department of Audiology

Title of research: Occupational hearing loss among workers exposed to industrial chemicals and noise: a study in a paint industry and among car sprayers.

Principal Investigator: Deborah Tetteh
Department of Audiology
Professional MSc Audiology
Mob: 0208279800; email: datty24@yahoo.com

General Information about Research

Under the supervision of Professor Amedofu, G.K., and Dr Anim Sampong of the University of Ghana School of Allied Health Sciences, I, Deborah Tetteh, a graduate student in research of the Department of Audiology. I am conducting research on occupational hearing loss among workers exposed to organic solvents and noise: a study in the paint industry and among automobile sprayers.

The purpose of the study is to find out if hearing loss occurs in the paint industry. The process will involve checking your hearing status and measuring your hearing sensitivity with a computerized audiometer. This data will be analyzed and kept confidential.

Possible Risks and Discomforts

There are no risks for participation in this study since the testing equipment and procedure does give any side effect.

Possible Benefits

Participating in the study provides you with the opportunity of knowing your hearing status and the presence or not of any hidden hearing problem without any cost.

Alternatives to Participation

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In the event of any noticed problem the participant will be referred for follow-up for further testing and the necessary action as needed.

Confidentiality

All information provided will remain confidential and will only be reported as group data with no identifying information. All data, including test results will be kept in a secure location and only those directly involved with the research will have access to them.

Compensation

Participants who commute to have the testing done will have their results given freely. Voluntary Participation and Right to Leave the Research. Participation in this research study is voluntary. You have the right to withdraw at any time or refuse to participate entirely without any jeopardy to you whatsoever.

Contacts for Additional Information

For any information, clarification or questions about the study, please contact the principal investigator, Deborah Tetteh on 0208279800.

Your rights as a Participant

This research has been reviewed and approved by the Ethics and Protocol Committee of the School of Allied Health Sciences, College of Health Sciences, University of Ghana. If you have any questions about your rights as a research participant you can contact the EPC Office between the hours of 8am-5pm through the landline +233-302-687974/5 or postal addresses: Box KB 143, Korle-Bu, Accra.

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APPENDIX V VOLUNTEER AGREEMENT /CONSENT FORM

The document describing the benefits, risks and procedures for the research: occupational hearing loss among workers exposed to organic solvents and noise: a study in the paint industry.

I…… ……have been given an opportunity to have any questions about the research asked and answered to my satisfaction. I will like to take part in the study so far as my details will be kept confidential. I agree to participate as a volunteer

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APPENDIX VI

QUESTIONAIRRE FOR THE STUDY/CASE HISTORY

1. Name:……Age……gender……..

2. Department at work:……Duration of working……

3. Have u taken ototoxic drugs in the past 6moths (gentamincin,quinine) (YES/NO)

4. Have u had surgery in your ear before? (YES/NO)

5. Have you had infection in your ears before? (YES/NO)

6. Have you had discharge in your ears before? (YES/NO)

7. Have you ever worked in a noisy environment? (YES/NO)

8. Do you work with chemicals? (YES/NO)

9. Do you operate a machine which makes noise? (YES/NO)

10. Do you work with chemicals as well as work with noise? (YES/NO)

11. Do you wear protective device when working? (YES/NO)

12. OTOSCOPY……tympanometry……..

13. PTA

AIR CONDUCTION THRESHOLD

	250Hz	500Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000HZ
RIGHT								
LEFT								

BONE CONDUCTION *0.5 – 4 kHz only, where air conduction thresholds is > 20 dB HL

	500Hz	1000Hz	2000Hz	3000Hz	4000Hz
RIGHT					
LEFT					

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APPENDIX VIII

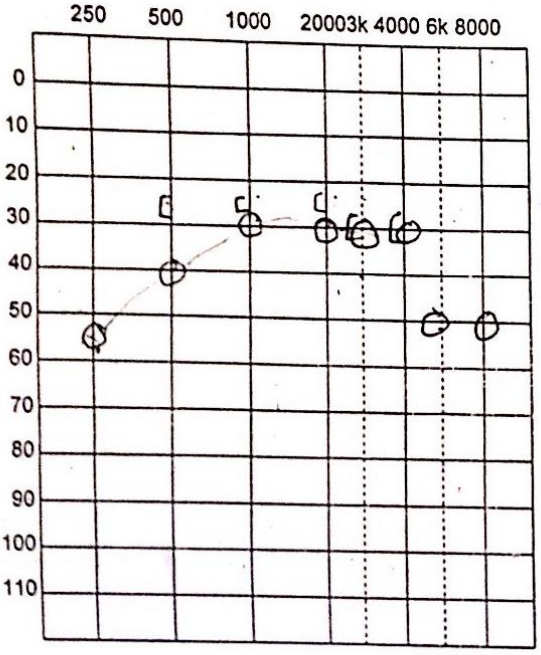
PROTOCOL NORMS OF KORLE BU

DATE:	
AUDIOMETER:	
EXAMINER:	
NAME:	
ADDRESS:	
PHONE:	DOB: SEX:
REFERRED BY:	
TEST RELIABILITY: ___GOOD ___FAIR ___POOR	

KORLE BU TEACHING HOSPITAL
HEARING ASSESSMENT CENTRE

AUDIOLOGICAL EVALUATION

Korle Bu Teaching Hospital
PO Box 77
KORLE BU, ACCRA
Tel: 233-302-660340
Email: korlebu@ghana.com
Web Site: www.korlebu.com



AUDIOGRAM KEY

	R	L
A/C UNMASKED	O	X
A/C MASKED	Δ	□
B/C UNMASKED	<	>
B/C MASKED	[	]
SOUNDFIELD	S	

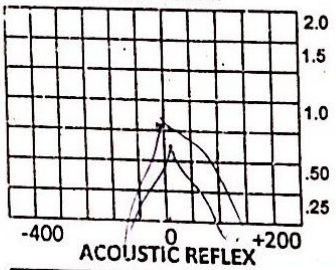
SPEECH

	RIGHT	LEFT
SAL		
SRT		
DISCRIM/%		
UCL/MCL		

TYMPANOMETRY

NORMAL VALUES	RIGHT	LEFT
ECV (0.2-2.0 ml)	0.87	0.89
PEAK COMPLIANCE (0.2-2.0 ml)	0.58	0.65
PEAK PRESSURE (-150→100 daPa)	5	-4

TYMPANOGRAM



OTOACOUSTIC EMISSIONS

OAE	PASS	FAIL
RIGHT		
LEFT		

ACOUSTIC REFLEX

ACOUSTIC REFLEX	500	1k	2k	4k
RIGHT				
LEFT				

IMPRESSIONS:

RECOMMENDATIONS:

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APPENDIX IX : SCORE SHEET FOR PRESENCE OF HEARING LOSS

GROUPS	NON EXPOSED GROUP	SOLVENT AND NOISE ONLY	NOISE ONLY

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APPENDIX X BINAURAL PURE TONE AVERAGE OF GROUPS

PARTICIPANTS	UNEXPOSED/37	SOLVENTS AND NOISE/46	NOISE ONLY/32
1.	20.00	20.20	26.70
2.	15.30	17.12	21.14
3.	17.20	15.30	15.10
4.	15.10	15.00	17.20
5.	20.00	20.00	20.00
6.	17.85	31.79	13.57
7.	15.71	13.57	21.47
8.	13.57	21.45	30.20
9.	15.00	17.0	20.15
10.	13.93	21.14	17.85
11.	15.00	17.12	21.42
12.	15.00	15.10	21.18
13	20.00	13.57	50.30
14.	13.57	17.12	66.20
15.	17.14	31.55	20.00
16	15.30	15.20	15.10
17	26.70	17.20	15.26
18	13.57	17.85	17.85
19	17.85	31.55	22.54
20	21.42	15.10	23.40
21	21.47	18.88	13.54
22	17.12	65.02	15.00
23	15.20	17.20	15.00
24	19.50	20.00	18.23
25	20.00	17.30	19.50
26	21.00	18.00	13.54
27	12.50	45.20	55.24
28	17.20	15.10	21.50
29	13.72	17.56	20.00
30	20.00	18.25	22.40
31	18.21	13.71	15.20
32	20.00	15.00	19.50
33	13.12	15.00	
34	18.02	18.79	
35	13.25	20.05	
36	18.00	20.00	
37.	17.52	60.20	
38.		13.52	
39.		18.51	
40.		15.07	
41		20.05	
42		17.32	
43		16.50	
44		17.32	
45		62.33	
46		41.34	

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APPENDIX XI: BILATERAL MEAN OF LOW AND HIGH FREQUENCY PURE TONE AVERAGE

PARTICIPANTS	UNEXPOSED/37		SOLVENTS AND NOISE/46		NOISE ONLY/32	
	HIGH	LOW	HIGH	LOW	HIGH	LOW
1.	22.64	16.66	26.25	16.86	34.69	23.36
2.	16.54	11.96	22.25	13.78	27.47	17.80
3.	19.00	13.86	19.88	11.96	19.62	11.76
4.	16.28	11.76	19.49	11.66	22.35	13.86
5.	22.65	16.66	25.99	16.66	25.99	16.66
6.	22.65	14.51	41.31	28.45	17.63	10.23
7.	19.85	12.37	17.63	10.23	27.89	18.11
8.	17.07	10.23	27.87	18.11	39.24	13.66
9.	14.29	11.66	22.09	13.66	26.18	26.86
10.	16.12	10.59	27.47	17.8	23.19	16.81
11.	14.76	11.66	22.25	13.78	27.83	14.51
12.	16.15	11.66	19.62	11.76	27..52	18.08
13	16.15	16.66	17.63	10.23	65.36	17.84
14.	22.65	10.23	22.25	13.78	86.02	46.96
15.	14.29	13.8	41.00	28.21	25.99	16.66
16	18.93	11.96	19.75	11.86	19.62	11.76
17	16.54	23.36	22.35	13.86	19.83	11.92
18	31.35	10.23	23.19	14.51	23.19	14.51
19	14.29	14.51	41.00	24.21	29.29	19.20
20	19.85	18.08	19.62	11.76	30.41	20.06
21	24.49	18.13	24.53	15.54	17.59	10.2
22	24.56	13.78	84.48	61.68	19.49	11.66
23	18.91	11.86	22.35	13.86	19.19	11.66
24	16.41	16.16	25.99	16.66	23.34	14.89
25	22.00	16.66	22.48	13.96	25.34	16.16
26	22.65	17.66	23.39	14.66	17.59	10.2
27	23.95	9.16	58.73	41.86	71.78	51.9
28	12.90	13.86	19.62	11.76	27.94	18.16
29	19.01	10.38	22.82	14.22	25.99	16.66
30	14.49	16.66	23.71	14.91	51.98	36.66
31	22.65	14.87	17.81	10.37	19.75	11.86
32	20.32	16.66	19.49	11.66	25.34	20.2
33	22.65	9.78	19.49	11.66		
34	13.71	14.68	24.42	15.45		
35	20.08	9.91	26.05	16.71		
36	13.88	14.66	25.99	16.66		
37.	20.05	14.18	78.22	56.86		
38.			17.57	10.18		
39.			24.05	15.17		
40.			19.58	11.73		
41			22.66	14.10		
42			22.51	13.98		
43			21.44	13.16		
44			19.67	11.8		
45			80.99	58.99		
46			58.99	38.00		