KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

INSTITUTE OF DISTANCE LEARNING

DEPARTMENT OF ENVIRONMENTAL SCIENCE

A STUDY OF OCCUPATIONAL NOISE EXPOSURE AMONG GOLD MINERS AT ANGLO GOLD ASHANTI LIMITED (OBUASI)

THIS DISSERTATION IS PRESENTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE MSc. DEGREE IN ENVIRONMENTAL SCIENCE

BY

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JULY, 2011

DECLARATION

"I declare that I have wholly undertaken this study reported therein under the supervision of Dr. Ebenezer J. D. Belford and that except portions where references have been duly cited, this dissertation is the outcome of my research".

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ACKNOWLEDGEMENTS

The writing of this dissertation has been a bit challenging but I am very grateful to God that, He that begun a good work in me has brought it to a successful end.

I wish to acknowledge the timeless assistance and guidance given to me by my hard working and intelligent supervisor, Dr. Ebenezer J. D. Belford who has also been a father supporting me in all my endeavours.

The successful completion of this work is also attributed to the persistent assistance, correction and encouragement received from Mr. Baffour, Mr. Botwi, Dr. Benye and Madam Georgina, all of AngloGold Ashanti Limited (Obuasi).

The list would not be completed without acknowledging Mrs. Akpe Bentoom who stood by me throughout my education and whose encouragement kept me going.

I am indebted to Doris, Evelyn, Daa Joe and Mohammed for assisting and encouraging me throughout my work.

Finally, I thank all my friends and all who in one way or the other contributed to the success of this work.

ABSTRACT

Underground and surface gold miners working at AngloGold Ashanti Limited (Obuasi) are potentially exposed to high noise levels from the mining activities, especially noise emitted by the heavy mining equipments. However, occupational exposures to hazards in mine environments have not been adequately characterized and identified. In a bid to assess the noise miners working at AngloGold Ashanti Limited (Obuasi) are exposed to, a study of the occupational noise exposure among gold miners was investigated using a Mini-Sound Level Meter, Noise Dosimeter and through a questionnaire survey. A total of 275 miners were sampled from 4 underground operating shafts and 7 above ground workshops from 8.00 am to 4.00 pm, twice weekly, for 5 months to estimate the occupational noise exposure levels and health impacts. Noise Dosimeter microphone was located at the hearing zone of the gold miner during the full-work period of 8 hours and measurements recorded at the end of each work shift. Results obtained indicates that there is a statistically significantly difference between the mean occupational noise exposure within the sites of mining activities for Continuous Equivalent Level, $L_{Aeq.8hrs}$ (92.5 $\pm$ 9.00dB (A)) and that of the recommended standard of 85dB (A). The research findings indicated that the primary risk of exposure to noise by gold miners comes from work activities such as drilling, blasting, machine operating, processing, ventilation and transportation. The mean sound pressure levels of exposure of underground miners was 10.9% above the recommended standard of 85dB (A) whiles exposure of surface miners was 2.7% above the recommended standard of 85dB (A). All occupational types were found to be susceptible to noise levels which were potentially harmful. Drillers, Machine Operators, Blast men, Carpenters and STP workers were especially susceptible since their minimum noise level exceeds the recommended standard of 85dB (A). The incidence of tinnitus was found in 56.8% of the miners sampled whilst annoyance, high blood pressure and headaches were found to be 23%. The results of this study will provide useful information for audiologists to better deal with diagnostic testing and aural rehabilitation of the miners. The study highlights that miners are exposed to hazardous noise levels and therefore the need for greater awareness of the effects of noise on the hearing acuity of miners and the need for strict enforcement in the use of hearing protective devices.

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LIST OF ABBREVIATIONS

ABS	Australian Bureau of Statistic
ACGIH	American Conference of Government Industrial Hygienist
ANSI	American National Standard Institute
ANOVA	Analysis of Variance
ARHL	Age Related Hearing Loss
ASA	American Standard Association
BHI	Binaural Hearing Impairment
DTH	Down the Hole Drill
DME	Department of Mineral and Energy
dB(A)	Decibel (unit of sound) by the A-weight
EPA	Environmental Protection Agency
GEMET	The General Multilingual Environmental Thesaurus
GCS	George Cappendel Shaft
HEG	Homogenous Exposure Group
Hz	Hertz (unit of frequency)
ISO	International Standard Organization
KMS	Kwasi Mensah Shaft
LAeq8h	Equivalent sound levels, measured over an exposure period of 8 h.
LHD	Long Hole Drill
MSHA	Mine Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
NIHL	Noise-induced hearing loss
ND	Noise Dosimeter
OSHA	Occupational Safety and Health Administration
Pa	Pascal

P-value	Significance level
REL	Recommended Exposure Level
RMS	Root Mean Square
SABS	South African Bureau of Standard
SPL	Sound Pressure Level
SPSS	Statistical Package for the Social Sciences
TLV	Threshold Limit Value
T-test	A statistical test of the null hypothesis
TWA	Time Weighted Average
USA	United States of America
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

Prolonged exposure to noise can result in permanent damage to the auditory nerve and/or its sensory components (NIOSH, 1996). This irreversible damage, known as noise-induced hearing loss (NIHL) makes it difficult to hear and understand speech. NIHL is the most common occupational disease in the United States today, with approximately 30 million workers exposed to excessive noise levels or to toxic agents that are potentially hazardous to their hearing (NIOSH, 1996). The problem is particularly severe in all areas of mining (surface, processing plants and underground), with studies indicating that 70 to 90 percent of all miners have NIHL great enough to be classified as a hearing disability (NIOSH, 1996).

In the Obuasi Municipality (Ghana), the gold mining industry plays a vital role in the economy and life of many of the communities in the municipality. The result of the exposure to high levels of noise is the presence of auditory and non-auditory effects as mentioned above. Melnick *et al.* (1994) noted that the exposure of the human ear to high intensities of noise, results in a sensory-neural hearing loss or what is known as Noise-Induced Hearing Loss (NIHL). NIHL is characteristically a hearing loss where the damage incurred is chiefly to the cochlear hair cells. These hair cells are responsible for converting sound energy to electrical signals transmitted to the brain. This damage may be the result of direct mechanical trauma to the delicate organ of Corti structures or the result of overdriving the metabolically dependent processes of the inner ear (Miller *et al*., 1996).

An early analysis of NIHL in 1,500 coal miners revealed an alarming prevalence of severe hearing loss (NIOSH, 1976). For example, by age 60, more than 70 percent of the miners studied had a hearing loss of more than 25 dB, and about 25 percent had a hearing loss of more than 40 dB. Weeks (1995) reported that the policies and practices for preventing occupational hearing loss among miners are inadequate and noted that there are deficiencies in nearly every sector: surveillance of exposure or of outcome, analysis and intervention. A more recent analysis of NIHL in miners showed an apparent worsening of NIHL (NIOSH, 1996). This analysis of a private company's 20,022 audiograms for 3,449 miners indicated that the number of miners with hearing impairment increased exponentially with age until age 52, at which time 90 percent of the miners had a hearing impairment. NIOSH defines hearing impairment as an average hearing threshold level of 25dB or greater for the frequencies 1,000, 2,000, 3,000 and 4,000 Hz (NIOSH, 1996, 1997). The Federal Coal Mine Health and Safety Act of 1969 established requirements for protecting coal miners from excessive noise. Subsequently, the Federal Mine Safety and Health Act of 1977 broadened the scope to include all miners, regardless of mineral type (Code of Federal Regulations, 1997). Since the passage of these Acts, there has been some progress in controlling mining noise. In fact, data from more than 60,000 full-shift MSHA noise surveys show that, in general, the noise exposure of selected occupations has decreased since the 1970s (Seiler and Giardino, 1994). However, for these same surveys, the percentage of gold miners with noise exposures exceeding federal regulations, unadjusted for the wearing of hearing protection, was 26.5 percent and 21.6 percent for surface and underground mining respectively (Seiler and Giardino, 1994). Despite the extensive work with engineering controls, education and hearing conservation in the 1970s and 1980s, NIHL is still a pervasive problem in the mining industry (Federal Register, 1996). MSHA recently published new Noise Health Standards for Mining (Federal Register, 1999), and one of the changes is the adoption of a provision similar to OSHA's Hearing Conservation Amendment. Other requirements of the new regulations are a permissible exposure level (PEL) of 85dB (A) TWA8 (which stands for time weighted average – 8 hour and is defined as the sound level that if constant over 8 hours would result in the same noise dose as is measured) (Federal Register, 1999). Complicating the problem of NIHL in mining is that, much of the existing noise and worker-exposure information is outdated and has limited value for current research and engineering control decision-making. Again, these issues have received little attention in developing countries due to the widespread and culturally rooted lack of awareness regarding the importance of a safe and healthy working environment, and to the weakness of the institution responsible for the promotion and enforcement of better working conditions.

To address this problem of industrial noise pollution and its possible adverse effects on health requires factual and credible information relating to noise production and emission, the level of noise, the duration of exposure during a work life, as well as the effects that actually exist in our environment. Yet, at present, there is insufficient information to explain this great variation in exposure time for mining occupations and to understand this variability to identify appropriate solutions. Specifically, noise level data are needed to provide a time exposure history for workers in addition to further information on noise sources. This information will provide the basis for targeting and selecting engineering controls, in combination with administrative controls, and the use of personal protective equipment, to reduce noise exposures among the mining workforce.

It is therefore justifiable and imperative to embark on a study of this kind with the intention of contributing additional knowledge to the exposure of high level of noise, to estimate quantitatively the magnitude of noise pollution and to assess its effects on the miners, for the purpose of attaining best clinical practice with this population; for example awareness of expected hearing loss. Hearing conservation programmes need to be regularly reviewed, therefore the deep gold mining industry needs sound pressure levels information that will help to make decisions concerning it’s hearing conservation progarmmes, for example the information that needs to be conveyed to gold miners about the dangers to their hearing.

1.2 Main Objective

To determine the occupational noise exposure levels among gold miners at AngloGold Ashanti Limited (Obuasi).

1.2.1 Specific objectives

- To determine the magnitude of noise pollution at AngloGold Ashanti.
- To identify which occupational group is especially susceptible to noise level that is potentially harmful.
- To estimate the Sound Pressure Levels (SPL) from each operating shaft and activity area in the mines.
- To identify the symptoms of Noise Induced Hearing Loss (NIHL) among gold miners at AngloGold Ashanti limited.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Brief Historical Overview and Perspective of Noise Pollution

The problem of hearing loss from occupational exposure to noise dates from at least middle age where workers in professions such as blacksmithing, mining, church bell ringing were known to suffer such impairments (WHO, 1995). As early as 1831 “blacksmiths’ deafness” with the concomitant feature of tinnitus (referred to as “ringing and noise in the ears”) was cited in a medical literature (Berger *et al.*, 2003). One-half century later another medical article referred to as “boiler maker’s deafness” since the author at that time based his findings upon examination of 40 men from the steam - boiler shops in port land (Berger *et al*., 2003). The effect, namely loss of hearing was clearly identified but the mechanism was poorly understood. Berger *et al*. (2003) ascribed it to constant agitation of the joint of the ossicles, thereby causing alkalosis (stiffening due the growth of fibrous of any bony union), especially of the stapes. Mechanisms of prevention were also not known at the time. Berger *et al*. (2003) reported that men tried stopping their ears with cotton wool and pads but derived no benefit therefore: he had no alternative suggestions. At the same time in Scotland it was reported that men (also boiler makers) were prejudiced against use of cotton ear plugs because it would predispose them to catching cold when the plugs were removed at night.

Asamoah-Boateng (2002) noted the rising noise level in industries and pleaded for an international Board of Physicians to be set up to monitor the resulting hearing loss of factory employee. This concern was expressed due to the large number of people affected by the noise source. Quantitative studies on large numbers of subjects with permanent threshold shifts had to wait the development of noise-measuring equipments for noise intensities, and instrument for the measurement of hearing to determine hearing loss on the other hand. Noise measurement proved to be easier than hearing threshold determinations which at first focused on speech evaluation. Soon after the introduction of audiometric, Berger *et al.* (2003) observed dips at 4 kHz and published probably the first audiometric data demonstrating the typical frequency loss acquired by those exposed to excessive noise. In 1960, Noise in factories which was published by the Department of Scientific and Industrial Research (Asamoah-Boateng, 2002) clearly outlined the effects of excessive noise on the welfare, safety and work efficiency. This was followed by the Wilson Report (Berger *et al.*, 2003), which emphasized the risk of permanent hearing threshold shift above the 90dB (A) noise level.

In large part, serious and sustain interest in hearing conservation developed as a result of World War II, subsequent to which untold members of soldiers return home with hearing loss. In fact, one of the earliest regulations dealing with hearing conservation was the Air Force Regulation cited by Berger *et al*, (2003). Industrial Hearing Conservation Programmes began to appear in the late 1940s and early 1950s with some of the first reported programmes established in the aviation and metals industries. Government noise regulation followed in the late 1960s (Berger *et al.*, 2003) and became more prominent and widely enforced with the enactment of the Occupation Safety and Health Act (OSHA) of 1970 and promulgation of the noise standard in 1971 (Berger *et al.*, 2003). It took an additional decade for OSHA to produce the hearing conservation amendment (OSHA, 1988) which specified the details of an occupational hearing conservation program that was only hinted at in the original 1971 standard.

Clearly, the above literature and issues by other investigators indicates that concern for occupational noise exposure and its effect on the hearing on exposed population is relatively not a recent issue.

2.2 Understanding Noise Pollution

Why is there so much concern about the environment? Why are concepts such as: pollution, air pollution, water pollution, soil pollution, global warming, ozone, radiation, and noise pollution becoming more and more popular and attracting public opinion? Why is it now a worldwide major and political issue? The answer is clear and simple; impacts from the deterioration environment on human life are evident and tragic. Diseases and vulnerable health are traits of our modern life (Botkin and Keller, 2000). We live in a time where technology gives us a lot, but also adversely affect us.

One major issue due to technology is noise pollution. The noise pollution before technology is incomparable with the pollution of modern society, where many factors contribute and increase the problem widely; increasing population with urbanization and its implications such as increasing number of roads, rails and air traffic. We live in a noisy background; the upsetting noise of aircrafts, the disturbing noise from industry and noise from transportation annoy and exhaust us. Noise pollution has been recognized as a major threat to human well being. It has been said that noise in extreme limits, can damage hearing and can be classified as a hazard (WHO, 1999).

In a conference held in Rosario, Argentina, on September 29 and 30, 2000, participants agreed on the definition of the expression "Acoustic Violence" to refer to the new approach of considering noise pollution as an instant of violent behavior. This means that noise can not only be annoying but also damaging to the health. Even scientists said that, the growing levels of human-caused noise in the oceans is disrupting and/or killing whales, dolphins and other marine life (Sparrow, 2002).

The attempt to give a clear, comprehensive and reliable definition for noise is not simple. It is mainly subjective to a great extent, what is considered ordinary and enjoyable for someone is considered for others annoying and disrupting sound. As a result, it is difficult to provide a scale for the degree of annoyance caused by a sound. In general, noise is defined as: Harmful or unwanted sound in the environment, which in specific locals, can be measured and averaged over a period of time (GEMET, 2000).

Basic Concepts

Studying noise require the understanding of many basic and essential concepts and information which are involved in the study of noise such as the ear physiology, hearing process, sound and physical quantities for measuring the noise (frequency, noise intensity, sound pressure and sound pressure level and decibel).

2.3 Structure of the ear: The organ of hearing

The natural life requires hearing. The ability to know and discriminate what is moving around is giving us an outstanding survival advantages. Also, social activities depend largely on talk and speech communication. In our body the ear perhaps is the only part that gets or receives the noise. So understanding its physiology and hearing process is to understand why noise has large adverse effects. The human ear consists of three main parts: the outer ear, the middle ear and the inner ear (Howard and Angus, 2001), as shown in Figure 1

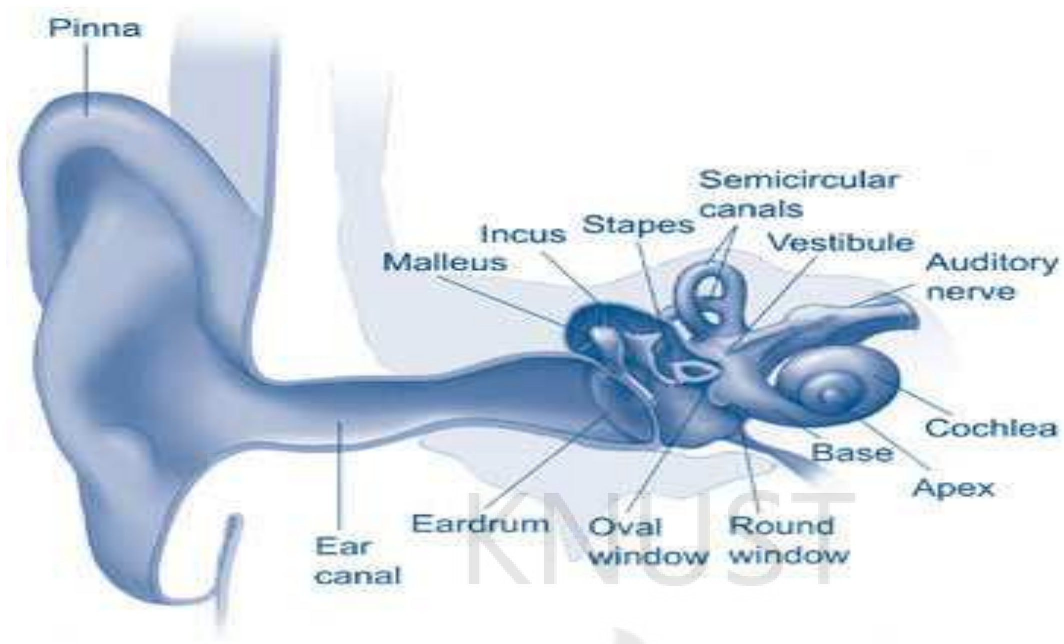


Figure 1: Anatomy of the human ear (Source: www.nidcd.nih.gov/health/hearing/noise.asp)

The outer ear consists of two portions, largely cartilaginous external tissue called the pinna or auricle and the auditory canal. This tube (auditory canal) connects the outer ear to the middle ear. After this comes the eardrum (tympanic membrane). This divides the external ear from the middle ear. The middle ear consisting of: auditory bones (the auditory ossicles), which are three tiny bones that are connected and transmit the sound to the inner ear. The bones are called the mallues, the incus and the stapes (Howard and Angus, 2001). The bones have more common names: hammer, anvil and stirrup respectively. The three bones form a system of levers linked together, hammer pushing anvil, anvil pushing stirrup. The bones double or often treble the force of vibration reaching the eardrum (Roberts, 2002). Mitigation of potentially harmful implication occurs via muscles of the middle ear. These muscles operate as safety apparatus to protect the ear against extreme vibrations from very loud noises (Howard and Angus, 2001).

The inner ear consists of:

1 – Cochlea (contains the nerves for hearing). The cochlea is the spiral tube that is coiled around the cochlear nerve. The cochlea has the main role of hearing process (Howard and Angus, 2001).

2 – Vestibule (contains receptors for balance)

3 – Semicircular canals (Howard and Angus, 2001).

2.4 Hearing Mechanism

Hearing starts with the outer ear. The sound waves (vibrations) pass through the auditory canal and strike the eardrum. The eardrum vibrates. Air molecules under pressure cause the eardrum to vibrate (Roberts, 2002). The vibrations are then passed to the auditory ossicles. The ossicles amplify the sound and send vibrations to the oval window (in the inner ear). The vibrations that reach the inner ear through the oval window cause a pressure changes that vibrate the perilymph, these vibrations are transmitted across the vestibular membrane to the endolymph of the cochlear duct. Almost all the sensitive, important and indeterminate job is done in the inner ear along basilar membrane. The nature of basilar membrane is important for frequency discrimination. The vibrations move the hairs which in turn excites the associated nerve fibers (Pickles, 1988). The location of the hair cells with the nerves is highly correlated with the frequency of the sound. According to Roberts (2002), loud sound excites nerves along a fairly wide region of the basilar membrane while a soft sound excites only a few nerves. Once the sound waves reach the inner ear, they are converted into electrical impulses which the auditory nerves send to the brain. The brain then transmits these impulses as sound (Roberts, 2002).

2.5 Sound

Sound can be defined as: any vibration in air or other medium, some types, of which are able to cause sensation of hearing (Truax, 1999). We hear sound because our ear respond to sound waves of high and low pressure travelling through the atmosphere; wave is produced by a force that vibrates the surrounding air molecules, colliding into other air molecules. Where the vibration composed of alternating compressions and refractions reaches the ear (Stansfeld, 1992).

2.5.1 Sound Intensity and Sound Pressure

Sound intensity is defined as the sound power per unit area. The basic unit is watt/m² or watt/cm². Sound intensity measurements are usually made relative to the sound threshold of hearing intensity I_o:

$$I_o = 10^{-12}\ \text{watts/m}^2 = 10^{-16}\ \text{watts/cm}^2 \text{ (Snyder, 2000).}$$

Sound pressure can be defined as difference between the instantaneous at a point in a sound field and the average pressure at that point (The American Heritage Dictionary of the English Language, 2003). It is the sound pressure rather than the intensity of the sound wave which our ear react to. When a vibrating body moves in air, it creates a slight disturbance of the atmospheric pressure. The oscillating variations in sound pressure propagate in the form of a sound wave. Sound pressure may be measured in Newton per square meters (N/m^2) or Pascal (Pa), where 1 Pascal = $1N/m^2$ (Snyder, 2000).

2.5.2 The decibel

The decibel (dB) is a logarithmic scale used to denote the intensity or pressure level of a sound relative to the threshold of human hearing (WHO, 2000). A normative human ear can detect a pressure as small as 0.00002Pa or 20µPa, where the frequency of the sound is equal to

1000Hz (Howard and Angus, 2001). This reference pressure level has been internationally agreed upon, and it is usually called the threshold of hearing (Barlow and Mollon, 1982). The pressure variation within the range of perception by the human ear lies between 20µPa (audio threshold) and 200Pa (pain threshold) (Roberts, 2000). It is impossible to fit the spectrum of more than 10^7 Pa on the scale of an instrument. It was further found that the reaction of the ear was not linear but logarithmic in proportion to the applied stimulus (Sullivan and Faulkner, 1976).

The above problems are overcome by using logarithmic scale, known as the decibel (dB). The equation that gives the decibel can be written as:

$$\mathrm{dB} = 20\log[\frac{P}{P_0}]$$

Where p is measured in sound pressure and p_o is the reference sound pressure which is equals to 0.00002Pa. So the threshold level takes the value of 0 decibels (0 dB).

2.5.3 A-Weighted decibels dB (A)

As a rule, sounds consist of a mixture of high, medium and low frequency segments. The human ear perceives these frequency segments with various degrees of sensitivity, low frequency sound of the same decibel dB level are not heard as loud as high frequency sounds (Roberts, 2002). In other to reflect this property of the ear, measuring devices are equipped with acoustic filters. The acoustic filter “A” shows the best correspondence between ear and measuring devices for the usual environmental sounds (Harris, 1997). Practically all noise is measured using the “A” filter. The corrected sound volume is therefore given in “dB (A)” (Howard and Angus, 2001).

2.5.4 Loudness

Loudness is a sensation in the mind of the individual observer, depending on the intensity of the sound (Asiedu and Baah-Yeboah, 2002). It's acceptable that sound energy (vibrations) that enter the ear is converted to neurological impulses (Pickles, 1988), with all the neural processing points along the way. The psychological sensation of loudness is related to the intensity of the energy carried by the sound waves. The wavelength of these sound waves is sensed as the pitch of the sound, whereas the amplitude of the waves is perceived as loudness. Pitch is related to frequency where frequency is a measure of how frequently a vibration repeats itself (oscillates) in a second (Traux, 1999).

Loudness isn't a physical quantity, but fairly a personal sensation that humans have as part of our hearing. It is related generally to the size or closeness of a sound source, other factors are also involved, frequency, spectral content, the presence of other sounds, place, time of exposure, the recent history of sound perceived. Loudness is a very complex sense (Howard and Angus, 2001).

The acoustical characteristics of speech, sound, music and noise can be measured with considerable precision using appropriate instruments. The results also can be expressed in terms of fundamental parameters. By contrast the full and comprehensive interpretation of hearing mechanism is not completely understood. So it cannot be expressed in terms of physical parameters. This leads to statistical manipulation to understand the issue (Roberts, 2002); it becomes an objective and personal opinion.

2.6 Sources of Noise Pollution

According to World Health Organization's Guidelines for community noise, aircraft noise is more annoying than road traffic, which in turn is more annoying than noise from railways.

Furthermore, transportation noise not only produces temporary annoyance, but is a cause of lasting health impairment (WHO, 1999).

2.6.1 Transportation

While many sources are confined inside buildings and walls, away from public, noise from transportation propagates into the surrounding annoying large and various portion of peoples. This source is important because of large and growing number of it.

2.6.1.1 Road traffic

Traffic noise is an important source or may be considered as the most widespread source, which constitute an important environmental health problem for the people exposed (Purden, 1980). While noise from many sources is kept inside buildings and walls, noise from transportations is affecting major portion of people. The engines, the friction of the wheels over the road surface, the intensity of traffic and travel speed are considered the major sources of road noise (Sarraj, 2001). Noise level is strongly related to speed. There is also convincing evidences that along major highways arterials in interurban areas, noise emissions alter the living environment of wildlife species (Rodrigue, 2003).

A study performed in Sydney (ABS, 1997), showed that 1.5 million residents were exposed to outdoor traffic noise levels which was considered as undesirable (between 55 and 65 dB (A)). In Europe, the population exposed to noise levels above 65 dB (A) increased from 15% in 1980s to 26% in the early 1990s (WHO, 2000). Again, available evidence from WHO underlines that around 45% of the population in developed countries live in high levels of noise intensity (over 55dB) generated by road transportation (WHO, 2000).

2.4.1.2 Air traffic

Air transportation noise constitutes a considerable portion of total noise emission by transportation. Air transportation took a growing weight in inter-city transportation, where the jet engine is used; as a result, noise emissions have increased considerably. The most affected areas are localized nearby airports (Rodrigue, 2005). Noise essentially comes from several sources; the jet engine, the aerodynamic friction, and ground craft operations. Noise from aircraft operations is having direct impact on residential areas around airports. The effect is distributed along major approach and takeoff lanes (Fidell, 1990).

The impact of noise is greatest near close to the airport itself and under the flight path. Daytime aircraft movement at Heathrow, Gatwick, Stan steel and Manchester airports (carrying 126 million passengers) caused moderate disturbance to 69500 people over 83.7km^2 in 2002 (Ormerod, 2004).

2.6.1.3 Rail traffic

Rail transportation noise constitutes 10% of total noise emissions by transportation (Geography, 2003). The two main sources of noise relating to rail traffic, first is the operation of the rail network with all its implications, the operation of trains, which include the type of engines (mostly diesel), the speed of the train, friction of the wheels over the rails, track type, conditions and whistle blowing. Second are the maintenance and construction processes of rail infrastructure (EPA, 1993). The level of exposure is obviously related to the importance and location of rail transportation infrastructure usually in the urban areas where the major transshipment functions are performed. Rail noise can be considerable, but generally affects a far smaller group of population than road or aircraft noise as it is generally confined to residents living along rail lines in urban areas (ABS, 1997).

2.6.2 Construction noise

The noise from construction is a major source of noise. Construction noise sources include highway construction, air compressors, loaders, cement mixers, welding, hammering, dump tracks and pavement breakers. Construction equipments are often noise producing due to its nature or because of neglecting maintenance. Building operations are often carried out with considerable noise (WHO, 1999; Suter, 1991).

2.6.2.1 Construction noise and building services noise

Building construction and excavation work can cause considerable noise emissions. A variety of sound comes from cranes, cement mixers, welding, hammering, boring and other work processes (WHO, 2000). Construction equipment is often poorly silenced and maintained, and building operations are sometimes carried out without considering the environmental noise consequences. Street services such as garbage disposal and street cleaning can also cause considerable disturbance if carried out at sensitive times of day (WHO, 1999; Suter, 1991). Ventilation and air conditioning plants and ducts, heat pumps, plumbing systems, and lifts (elevators), for example, can compromise the internal acoustical environment and upset nearby residents.

2.6.2.2 Domestic noise and noise from leisure activities

In residential areas, noise may stem from mechanical devices (e.g. heat pumps, ventilation systems and traffic), as well as voices, music and other kinds of sounds generated by neighbours (e.g. lawn movers, vacuum cleaners and other household equipment, music reproduction and noisy parties (WHO, 1999)). Aberrant social behavior is a well-recognized noise problem in multifamily dwellings, as well as at sites for entertainment (e.g. sports and music events). Due to predominantly low-frequency components, noise from ventilation systems in residential buildings may also cause considerable concern even at low and moderate sound pressure levels.

The use of powered machines in leisure activities is increasing. For example, motor racing, off-road vehicles, motorboats, water skiing, snowmobiles etc., and these contribute significantly to loud noises in previously quiet areas (WHO, 2000). Shooting activities not only have considerable potential for disturbing nearby residents, but can also damage the hearing of those taking part. Even tennis playing, church bell ringing and other religious activities can lead to noise complaints (WHO, 2000). The national noise survey in US found that noise from barking dogs and roads traffic have the greatest impact on residential communities (EPA, 1993).

Some types of indoor concerts and discotheques can produce extremely high sound pressure levels. Outdoor concerts, fireworks and various types of festivals can also produce intense noise (Clark, 1991). The general problem of access to festivals and leisure activity sites often adds to road traffic noise problems. Severe hearing impairment may also arise from intense sound produced as music in headphones or from children's toys (WHO, 2000).

2.7 Occupational noise (Noise from industry)

Industrial noise is considered as one of the less prevailing noise sources. But these plants have plenty of machines and devices such as: motors, fans, cutting machines, compressors and transportation resources. These resources could be, or mostly transferred from the interior to the outside through open windows and doors, and sometimes through building walls (Hansen, 2001).

Occupational sources of noise constitute a considerable source of noise, this can be harmful for the worker, and every year about 30 million people in the U.S. are occupationally exposed to hazardous noise (OSHA, 2004). The sources of noise in work are several and varied but mainly have a relation to industrial machinery and processes such as gears, turbulent fluid flow, impact processes, electrical machines, internal combustion engine, pneumatic equipment, drilling, crushing, blasting, pumps and compressors. Exposure for more than 8 hours a day is risky (NIOSH, 1996).

2.7.1 Occupational Noise Exposure and Its Effects

Many investigations of noise pollution in various places of work have been conducted worldwide. High frequency sensory-neural hearing loss and other health problems of noise have been detected in most of the investigations.

In a study conducted by Asamoah-Boateng (2002) to determine the risk of noise exposure and its associated hearing problems among industrial and non-industrial workers, it was observed from the audiograms that exposure to noise levels of 85dB (A) was enough to produce significant hearing loss at 4 KHz. The hearing loss at 4 KHz among the industrial workers was observed to exceed the control group hearing levels at that frequency by an average 35dB (A). A conclusion was therefore drawn that, even though the experimental groups' average hearing loss did not fall within the compensable range, even for the longest exposure times, the hearing loss at 4 KHz was very significant and could produce measurable reduction in hearing sensitivity.

In an evaluation of literature on the incidence of occupational hearing loss in forestry workers in relation to the magnitude of the noise level measured at the work sites, an epidemiological study was performed between 1967 and 1974 (Rafalski *et al.*, 1976). The continuous 5 years study included 207 motor saw operators and 95 members of a control group. The results showed that noise produced by motor saw greatly exceeded generally adopted hygienic norms, thus creating definite health hazard for motor saw operators. About 68% of the motor saw operators were found to suffering from hearing loss after 7 years on the job. A study conducted by Mulugate (1992) in the wood working industry in Ethiopia also indicated that most wood working machines produce noise higher than the permissible level of 85dB (A), which is potentially hazardous. In the furniture industries, it has been shown that about 40% young persons' entering the industry develop noise-induced hearing loss by the end of the first 5 years of employment (Quainoo, 1992). Another study revealed that sound levels of saws can be as high as 106dB (A) (Goeltzer *et al.,* 2001).

The effect of exposure to noise in relation to the intensity as well as frequency characteristics of the noise was also investigated in Tanzania textile mills (Kahema *et al.,* 1981). They observed that, substantially high noise levels with considerable wide frequency range were found to be emitted by machines in the wearing and spinning sections of the factory. A peak noise level of well above the threshold limit value 85dB (A) and a hazardous frequency range of 2500-5000Hz were recorded. The effect of noise exposure was found to be proportional to the intensity and the spectral composition of the noise. The risk of hazards injuring ones hearing increased with the length of noise exposure. This was consistent with the fact that severity on noise depends upon factors such as: intensity level, duration of noise exposure, the frequency distribution and individual susceptibility to noise.

An investigation into the noise pollution levels and their impacts on exposed population at workplaces in different countries in Asia revealed that, approximately 38 percent (Singapore), 42 percent (Hong Kong), 83 percent (Korea) and 92 percent (Philippines) workers were exposed to noise levels above 85dB (A) in the workplaces. The hearing thresholds of those workers was evaluated and analyzed to assess the risk of the noise levels. He also reported that 12 percent (Korea), 15 percent (Hong Kong), 40 percent (Singapore) and 74 percent

(Philippines) had hearing loss in excess of 30dB (Asamoah-Boateng, 2002). The increase number of workers exposed to hearing intense noise and the adverse affects of hazardous noise on the hearing sensitivity of workers in these countries were thus established by the study.

McMahon and McManus (1988) monitored the noise exposure of 274 printing production workers in 34 establishments in New York City area. Results showed that 43 percent were exposed to 8 hrs time weighted average (TWA) noise exposure of 85 dB (A) or greater and that 14 percent were exposed to 90dB (A) or greater. A greater percentage of workers in the bindery departments were found to be exposed to potentially harmful noise more than the workers in the printing industry and that the former might be at risk of occupational hearing loss. The investigators therefore recommended that further research be carried out to determine the extent of the hearing impairment in this group of workers.

Workers who are engaged in different activities in an industrial plant and are exposed to hazardous noise in Karachi were also studied (Hassan *et al*., 1994). The results of the study showed that 14441(12%) workers out of the total 173,300 who registered with Sindh Social Security Institution in 1992 have noise-induced hearing loss (NIHL). Further review of investigation carried out by different authors regarding the progression of hearing deterioration during severe long exposure to noise in the industries shows a similar hearing loss in the range of 3-8 KHz from nearly all investigations. The fact that loss of hearing due to noise begin in light frequencies, with a dip in the audiogram at 4 KHz was also seen in this study (Melnick, 1994).

2.7.2 Non Auditory Effect of Noise on Man

So far, only the auditory effect of noise on the worker exposed to high level of noise have been described, but the implication of exposure to noise extends to non-auditory effect. Non-auditory effect are dependent on the noise and are known to include symptoms related to the automatic nervous system, as heightened skin temperature, increased pulse rate, vascular pressure, nausea, fatigue and decreased appetite (Edwards, 2008). Symptoms related to higher brain functioning have been documented including interference in thought processing and task execution. These symptoms result from greater concentration and listening effort needed when working in noise and in turn lead to irritability, aggression, depression and disturbance in sleep patterns (Edwards, 2008).

Another long-term non-auditory effect of NIHL has been shown to be the presence of tinnitus (Axelsson and Barrenas, 1992). Tinnitus can in many cases be debilitating for a patient and can influence moods, concentration, personality and some cases speech recognition. Tinnitus occurs in approximately one third of cases with a history of noise exposure (Edwards, 2008; Axelsson and Barrenas, 1992).

2.8 Gold Mining Industry

A more specific discussion about the gold mining industry is indicated at this point. The theoretical concepts and existing knowledge about NIHL have been well documented for a number of industry types as indicated above. Others include cotton and jute weavers (Edwards, 2008), hydroelectric and power workers (Celik, 1997), coal miners (Edwards, 2008), platinum miners (Nairn, 1984), automobile metal pressing plant workers (Bruhl *et al.*, 1994) and railway workers (Henderson and Saunders, 1998).

The gold mining industry has specific attributes that could impact on the characteristics of the NIHL found in gold miners. This include the fact that the working environment can be up to two kilometers underground and up to 10 kilometers into the mines on a vertical plane. Here, miners work on rock face for many hours a day, often exceeding the usual 8 hours working day, in the presence of high level of noise from machinery such as drilling equipments, ventilation equipments and transportation equipments in confined areas which may also impact on the acoustical effects that the noise has on the workers (Franz *et al.,* 1997).

Noise exposure levels associated with various jobs types in South African gold mining environment have been documented as far exceeding the legislated level of 85dB (A) (Kielblock *et al.,* 1991). The research organization of the Chamber of mines has reported that underground and surface mining equipments such as jackhammer, pneumatic drills, ball mills, air compressor, stoping and developing equipments and equipment for bending, riveting, grinding and cutting steel plate are known to emit noise levels of up to 110dB (A) (Schroeder *et al.,* 1980).

Recent research has resulted in updated and comprehensive knowledge on the intensities and spectrum of the noise to which miners are exposed, and information for conservation programme is now available (Franz *et al*., 1997). This extensive research into the emission level and spectrum of noise in mining environment showed that "all production personnel are at considerable risk with regards to noise exposure" and noise emission levels and particularly worker exposure level in conventional gold and platinum mining appear to have increased (Franz *et al*., 1997), due to the need for increased productivity. These circumstances will of course impact on the hearing of workers.

Kielblock *et al*. (1991) have noted that although their research results were based on constraints applying to platinum miners, gold miners were expected to have similar results. They found that only 2-3% of platinum miners exhibited binaural hearing impairment (BHI) higher than 25%, while 10% of all drill operators or their assistants fell into this category.

A number of factors in the development of NIHL have been researched as possible contributing reasons for the individual susceptibility. The main factor appears to be that of the age of the subject. Most of the research into the combined effects of age and noise exposure, has lead to the conclusion that the effect of NIHL and Age Related Hearing Loss (ARHL) are additive in nature (Tempest, 1985). Research in NIHL has resulted in the development of graphs indicating the expected hearing sensitivity levels for progressively older subjects in relation to the exposure periods (Edwards, 2008; Dobie, 1992; Kryter, 1998; Henderson and Saunders, 1998). Recent debate has however suggested that the correction factor for ARHL component of NIHL has more complex implication than simply subtraction from the hearing thresholds after noise exposure (Mills, 1992). The damage ear 'theory" which suggests that the already damage ear is at greater risk of further damage from continual noise exposure than a normal ear, is at the heart of this debate. Recent research also points to lower metabolic rates related to ageing as a factor that may increase the sensitivity of the ear to NIHL (Miller *et al.*, 1998).

Other factors that influence the individual susceptibility of NIHL featuring in recent research include the effects of dynamic physical exercise (Dancer *et al.*, 1992; Cristell, 1998), toxin (Dancer *et al*., 1992; Franz, 1996), drugs (Boettcher *et al.*, 1987) and smoking (Virokanas and Anttonen, 1995). These aspects of NIHL and possible influencing factors are all relevant to the worker in the mining industry and manifest in auditory and non – auditory effects.

2.9 Legislation

Due to the fact that the symptoms and characteristics of NIHL discussed in the previous section are factors that negatively influence the lives of workers, prevention measures have been legislated. The Gold Mining industry is governed by the code of practice for the measurement and assessment of occupational noise for hearing conservation purposes as laid down by the South African Bureau of the Standards Documents (1992) and as prescribed by the mines and workers Act 1956. The code of practice stipulates standards for measurement and rating of working environment for conservation purposes and also the necessary hearing conservation measures to be applied. The legislation ensures that hearing conservation measures are implemented in the case of workers for whom the noise-rating at 85dB (A) is exceeded. All employees who work in noise zones as rated by the legislation in SABS 1992 are expected to undergo audiometric screening test annually during the first three years of service and every two years thereafter. The referral threshold shift requires referral for diagnostic audiology to an audiologist who is registered with the Health Professional Council who performs diagnostic audiology. If diagnostic audiology test reveals that the permanent shift in the hearing threshold was caused by exposure to noise, then a reportable incident as stated by Occupational Health and Safety Act 1993 must be registered.

Audiology requires measurements of binaural hearing levels for at least 500Hz, 1000Hz, 2000Hz, 3000Hz, 6000Hz and 8000Hz so as to bring the audiologist to the conclusion that the permanent shift of hearing is caused by exposure to noise (SABS, 1992). However, in many cases the validity of the hearing test result is in question due to malingering on the part of patient. Further audiologist testing is often carried out in practice to validate results, and in many cases simply to obtain results, as continued malingering hampers the diagnostic process. The malingering is due to the prospect of receiving financial compensation for permanent hearing disability. This financial compensation cost the industry a great deal and could be prevented through effective Hearing Conversation Programmes (Edwards, 2008).

2.10 Conservation of Hearing

As mention above, an important aspect of NIHL is that it can be prevented (Melnick, 1994). The effort put into NIHL research demonstrates the concerted attempt to improve information, so that informed decision can be made about ways to prevent NIHL. Due to the fact that noise and hearing are measurable factors, Damage Risk Criteria have been drawn by Scientist and professionals in the field of NIHL. These criteria specify the noise exposure limit for workers in attempt to reduce the risk of hearing loss (Tempest, 1985; Melnick, 1994; SABS, 1996). Development in technology, both in the fields of measurement of hearing and in the most effective reduction of noise, open new possibilities for improve conservation. They provide procedures whereby specific details of worker's hearing loss can be monitored to give early indication of subtle alteration to hearing function (Sallutio *et al.*, 1998).

Recent research has suggested possibilities of further preventing NIHL by pharmacological means (Abdulla, 1998) and by means of sound conditioning or prior exposure to low-level noise (Canlon and Dalgi, 1996). The process of prevention of hearing losses is legislated and requires that hearing conservation programmes must be reviewed regularly to ensure their effectiveness. In areas where the noise level limit equals or exceeds 85dB (A), reduction of noise level is the first step in attempting to conserve hearing of workers. The engineering of noise reduction may take the form of acoustically insulating either the source of the noise or the operator. In areas where the noise rating level cannot be reduced below 85dB (A), the area must be clearly demarcated using mandatory signs to indicate a noise area. All employees entering the noise zones are then obliged to wear hearing protectors that comply with regulations (SABS, 1996).

Wearing of hearing protectors needs to be monitored and employees who works in noise zones must undergo the specified audiometric testing in an annual or biannual basis, due to the fact that hearing protectors do not provide adequate protection under all circumstances (SABS, 1996).

2.11 Instrumentation (Mode of Construction and Principle of Operation)

2.11.1 The Mini-Sound Level Meter (SLM)

The Mini-Sound Level Meter is the fundamental instrument used to measure noise. It is designed to estimate the loudness level sensitivity of the human ear. It gives objective, responsible measurements for the pressure level. This involves a complex work to acquire the frequency range, spectral weighting of the sound, along with the application of time constants, and calculation of equivalent continuous level. The microphone converts the sound to an equivalent electrical signal, which varies with the acoustical signal. The output signal from the microphone is very small and needs to be converted in the preamplifier before further processing takes place (Manual Instructions for Sound Level Meter).

The sound level meter calculates the A- and C-weighted Peak and Root Mean Square (RMS) values simultaneously. It contains one A - weighting and one C - weighting as well as one Peak and one RMS detector. After detection of the RMS and Peak values, the signals are digitalized in the analogue-to-digital converter. The level signals are represented by digital signals. They are processed by micro-computer which also controls the display, convert the values to decibels and calculate the equivalent continuous Sound Pressure Level (L_{eq}) and the A-C value. The time constant is also involved in the signals by the microcomputer. The sound level meter is placed to avoid nearby reflecting surfaces and be far enough from the source. The Mini-Sound Level Meter essential components block diagram is indicated in Figure 2.

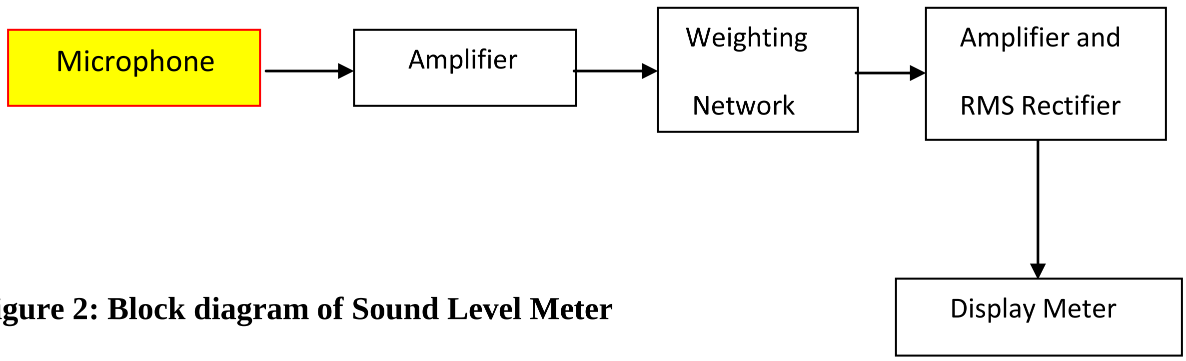


Figure 2: Block diagram of Sound Level Meter

2.11.2 Personal Noise Dosimeter

Personal Noise Dosimeter is used for monitoring the noise exposure of workers particularly in situations where a conventional noise dosimeter with a remote cable microphone might not be the most convenient method.

Figure 3 illustrates the components and processes generic to most Personal Noise Dosimeter. The specific components are as follows;

- Microphone
- Amplifier
- Weighting networks
- RMS Outputs
- Display meter
- Computer

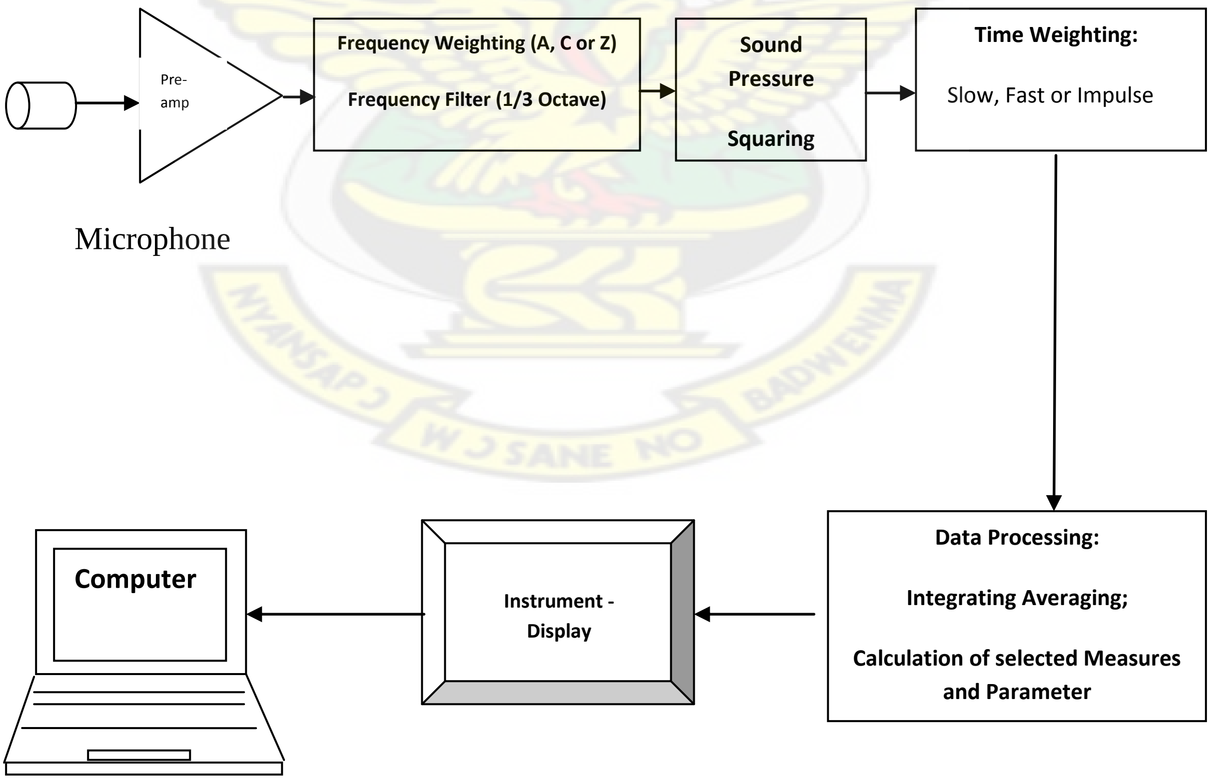


Figure 3: Components and processes of Personal Noise Dosimeter

When sound deflects the microphone's pressure-sensitive diaphragm, an electrical signal is sent to the preamplifier, which boosts the signal to a usable level before sending it to the frequency weighting filters (Manual Instructions for Sound Level Meter). The most basic personal noise dosimeter provide selectable weighting that allow the user to choose A-, C- or Z- weighting by means of the set up mode.

The filtered sound from the preamplifier, which corresponds to the pressure of the sound, is squared to produce a waveform proportional to the sound's instantaneous power.

The upper right block in the figure represents exponential averaging (time weighting) with selectable time-weighting which allow the user to set the speed of response to varying levels of sound. The lower right block in figure 3 represents the data processing stage, where measurement results are integrated to calculate the root mean square or average sound pressure level, the maximum, minimum and peaks, as well as various other measures selected by the user. The measurement results are displayed on the instrument or the results are transferred to a computer for further analysis, permanent storage and generating reports.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Survey of study area

A reconnaissance survey was conducted in the mine site to determine workers activity areas and the distribution and variation of occupational noise levels within study site.

3.1.1 Description of study area and site: Location and Size

The Obuasi Municipality is one of the 26 districts of the Ashanti Region and was created as part of the government's effort to further decentralized governance. It was carved out of the erstwhile Adansi West District Assembly on the strength of executive instruments (E. I.) 15 of December, 2003 and Legislative Instrument L. I. 1795 of 17th March, 2007. The Municipality is located at the southern part of Ashanti Region between latitude 5.35N and 5.65N and longitude 6.35N and 6.90N. It covers a land area of 162.4sqkm. There are 53 communities in the Municipality which share 30 electoral areas. It is bounded to the east by Adansi South, west by Amansie Central and to the north by Adansi North, to the south by Upper Denkyira District in the Central Region (Fig. 2). It has Obuasi as its Administrative Capital where the famous and rich Obuasi Gold Mines, now AngloGold Ashanti limited is located. The population of the Municipality is estimated at 205,000 using the 2000 Housing and Population Census as a base and applying a 4% annual growth rate.

Figure 4: Map of study area.

3.2 Calibration of Instruments

The noise exposure data was recorded using a mini Sound Level Meter (SLM) Bruel & Kjaer investigator Type 2250 – L and three unit of noise logging Casella CEL Dose Badge (dBadge) with integrated Display.

In accordance with regulations (SABS, 2004) the SLM together with noise dosimeter was calibrated before and their usage. This is because the instrument may have been subjected to vibration, shock and excessive heat on their way to measurement site which could have impaired the accuracy of the instruments. The following general procedures were followed for the calibration;

- The microphone was attached to the Sound Calibrator (Bruel & Kjaer Type 4231)
- The calibrator was switched on and its display was allowed to be steady

- It was ensured that the meter display was adjusted to correspond with the specified calibrator's output.
- The result was subsequently served /accepted and
- The calibrator was switched off.

3.3 Data Collection

3.3.1 Noise Measurement

3.3.1.1 Measurement of underground noise using the Personal Noise Dosimeter

The underground noise levels were measured using the Personal Noise Dosimeter (Dose badge) Casella CEL dBadge with integrated display. This instrument was effective for measuring underground noise levels in deep gold mining environment where miners move from one point to the other. Sampling strategy was referred to NIOSH Occupational Exposure Sampling Strategy Manual and ISO 9612 Acoustics – Guidelines for the measurement and assessment of exposure to noise in the working environment (ISO, 1997).

Data was collected from the underground miners working from four different operating shafts in the mines namely; Adansi (AD), Sansu (SAN), George Cappendel (GC) and Kwasi Mensah (KM). Data was obtained from each shaft on twelve different occasions. Sampling was done on Mondays and Fridays for five months (September to January) for the day shift from 8:00 am to 4:00 pm. The total working hours for the day shift is 8 hours (full work shift).

Underground miners' exposures to noise levels were determined from five miners from each shaft. They were randomly selected and administered with the Dose badge after they had completed a questionnaire.

Dosimeters were calibrated at the beginning and end of each shift. Full shifts were measured using slow response and A-weighting, and data recorded. The data was set to the ACGIH recommended level. For each dose badge issued records such as the instrument identification and serial number as well as the name, occupation and workplace (operating shaft and activity area) of the worker to whom it is issued were obtained.

The following were done to ensure employees cooperation with the noise measurements:-

- Employees were informed about the purpose of the measurement.
- Explanation was made to them about the importance of accuracy of noise data in assessing the need for noise control.
- Miners sampled were reminded about the importance of wearing the dose badge at all times during the measurements period.
- Miners sampled were advised to avoid shielding by the presence of employee and any other objects between the noise source and the microphone. The consequences of tampering with the microphone were also explained.
- Employees were advised to report to a designated location at the end of their shifts, where an official would remove the instrument, examine, unlock it and data recorded.
- Employees were also made aware that, the dosimeter is an expensive instrument and its replacement would be costly.

Consequently, miners sampled and their supervisors understood clearly the objectives of the study. All of them were very cooperative.

3.3.1.2 Measurement of surface noise using the Sound Level Meter

A visit was made to the selected workshops to inform the supervisors about the study and permission sought to take the measurements and to locate areas with hazardous noise levels occupied by surface miners. This was made possible after conducting a survey to designate certain areas with harmful noise levels (i.e. the red areas) where employees work.

Regular visits were made to measure the noise levels. Data was collected from the surface miners working from seven different workshops in the mines namely; Carpentry (CAR), Power Station (PST), Raise Boring (RBS), Plate Shop (PS), Machine Shop (MS), Sulfide Treatment Plants (STP) and Tailing Treatment Plant (TTP). Data was obtained from each workshop at five different times (i.e. measurements were taken for a period of 20-30 seconds) from four sampling points after the demarcation of the workshops. Sampling was done on Mondays and Fridays for five months (September to January) for the day shift from 8:00 am to 4:00 pm. The total working hours for the day shift was 8 hours (full work shift). The level of noise as recorded by the SLM was taken as the reference level of noise that was emitted from the workshop to which surface miners were exposed. Again to ensure that noise from all other sources besides the miner's own machines were accurately measured; the microphone of the mini-SLM was Omni- directional (i.e. one directional).

Samplings of surface miners' were conducted during production periods with miners still on the jobs. Noise measurements were measured at the position of the miners' head while they kept their normal work posture. Ten questionnaires were given out to ten surface miners who were randomly selected from each workshop visited. Different types of machines were studied in each of the workshops. The machines types were known to cause noise pollution. The main noise sources at the projects sites were as follows; Band Saw Machine (BSM), Copy Lathe Machine (CLM), Cross-Cut Machine (CCM), Chin-Saw Machine (CSM), Gullotine (GM), Hydraulic hummer (HM), Saw Cutting Machine (SCM), Spot-Welding Machine (SWM), Drilling Machine (DM), Centex Compressor (CC), Seal Air Compressor (SAC), Primary Water Pump (PWP), Secondary Water Pump (SWP), Millear (MR), Grinding Machine (GDM), Alimak (ALI), Diamond Drill (DD), Diamec Machine (DMM), Cutting Machine (CM), Lathe Machine (LM), Boring Machine (BM), Diesing Machine (DSM), Milling Machine (MM), Crusher (CRU), Oven (OV), Syntron (SM), Furnace (FUR), Extractor Fan (EXF), Hood/Fume Extractor (HFE), Bail Mill Machine (BMM) and Exhaust fan (EF).

The unit employed for expressing the values is the decibel (dB), set at A- weighting network. Again the SLM was set at the slow response throughout, since the level of the sound was steady and realized it did not vary for more than 5dB (A) (Bruel, 1986). The spectral characteristics of the noise measured in the various workshops could not be analyzed because the equipment for that purpose could not be secured. The SLM used was without a frequency analyzer.

3.3.2 Questionnaires

A questionnaire was designed to assess the effects of noise exposure among miners. The idea for the designing of questionnaire for the assessment of NIHL among miners was to generate information on all possible factors which might act in concert to cause hearing loss and to quantify those at the highest risk of NIHL. For this reason the presence of risk factors such as age, gender, occupation, medical history and non-occupational exposure were included in the questionnaire and their possible impact on the outcome evaluated.

The first step in the design of the questionnaire was to investigate current concerns regarding NIHL and sources of noise exposure among miners. The information gathered was used to determine what items should be included in the questionnaire. The five main topical items that were decided to be included in the questionnaire were:

- Symptoms on NIHL
- Possible sources of (occupational and non-occupational) noise exposure
- Medical history-particularly of diseases that could cause hearing loss
- The use of Hearing Protection Device (HPD)
- Records on the availability of NIHL (this was specifically meant for the Audio logical unit and workers of Occupational Health and Safety Dept).

Awareness, satisfaction, workplace information and other subjective effects related to health in terms of auditory and non- auditory effects were also included in the questionnaires.

A random sampling technique was used to select subjects from each of the workshops. Ten employees were sampled from each of the workshops. The list of the employees was obtained and the names of the employees were written on cards and the cards thoroughly shuffled and ten cards were randomly selected. This was made possible with the help of the workers from the Occupational Health and Safety Department and the Supervisors in the various workshops visited. Thus all employees were given the same chance of participating in the study. This ensures a firm basis for the application of significance tests and statistical methodology used to assess

3.4 Analysis Data

Data collected were analyzed by using Statistical Package for Social Sciences (SPSS) 17 software. Descriptive statistics were computed for 8 hours work shift and t-test was conducted to determine if mean noise level between occupational types had statistically significant differences. P-values less than 0.05 were considered statistically significant. Post hoc Duncan's tests (SPSS software), were done for pair-wise comparisons of significant differences in the relevant frequencies for each of the occupational types.

CHAPTER FOUR

4.0 RESULTS

4.1 Noise survey and demarcation of workshops at AngloGold Ashanti Limited.

A total of 275 workers, consisting of 205 underground miners and 70 surface miners participated in the study. The underground miners were sampled from the four operating shafts in the mines whilst the surface miners were from seven different workshops. The ages of the underground miners ranged from 20 to 55 whilst that of the surface miners ranged from 20 to 60 (Table 1). The years of service of the participating miners (both underground and surface) were divided into categories of 10 years for easier analysis (Table 2). Alternatively, only occupational categories that contained a sufficient number of subjects to give a reliable result (i.e. 10 or more miners) were used in the analyses (Table 3).

A visual representation of data by the use of tables and figures were performed to shed more light on the various research specific-objectives. Whenever applicable a descriptive statistics was also provided.

Table 1: Age distribution of selected underground and surface miners at AngloGold Ashanti Limited, Obuasi

Age	No. of miners	
	Underground	**Surface**
20 - 29	28	15
30 - 39	79	23
40 - 49	71	19
50 +	27	13
Total	205	70

Table 2: Categorisation of miners according to years of service

Years	No. of miners
1 - 10	41
11 - 20	105
21 - 30	98
31 - 40	31
Total	275

Table 3: Distribution of underground miners according to their type of occupation and years of service (Underground Only)

Occupation	Years of Service			
	1 - 10	**11 - 20**	**21 -30**	**31 - 40**
Drillers (DR)	3	9	8	0
Machine Operator (MO)	2	11	5	2
Loco Driver (LD)	4	8	6	2
Welder (WD)	3	9	7	1
Blast man (BT)	4	7	9	1
Supervisor (SUP)	0	5	7	8
Headman (HD)	2	8	8	2
Equipment Operator (EO)	2	10	7	1
Underground Electrician (UE)	2	5	6	2
Underground Carpenter (UC)	5	7	8	0
Underground Raise Borer (URB)	3	4	6	2

Table 4: Distribution of surface miners according to their type of occupation and years of service (Surface Only)

Occupation	Years of Service			
	1 - 10	**11 - 20**	**21 -30**	**31 - 40**
Carpentry (CAR)	3	9	8	0
Plate Shop (PS)	2	11	5	2
Power Station (PST)	4	8	6	2
Raise Boring Shop (RBS)	3	9	7	1
Machine Shop (MS)	4	7	9	1
Sulfide Treatment Plant (STP)	0	5	7	8
Tailing Treatment Plant (TTP)	2	8	8	2

4.2 Measurements of Sound Pressure Levels

4.2.1 Noise Dosimeter (ND) measurement from underground mining activities

Table 5 shows the results of the work shift dosimeter measurements in relation to underground miners. Noise levels measurements were obtained from 205 miners who participated in this study. Underground miners wore dosimeters for a single work-shift scheduled 8:00am to 4:00pm. All work-shift scheduled for 8hours (480minutes). The Mean Maximum noise level, L_{max} was 116.13 $\pm$ 8.42dB (A), Mean Minimum was 77.37 $\pm$ 5.42dB (A) and Mean continuous equivalent noise level, $L_{Aeq.8hrs}$ was 94.28 $\pm$9.11dB (A).

Table 5: Noise Dosimeter (ND) measurement from underground mining activities

Shafts	Minimum	Maximum	Range	Mean	Stand Dev
Adansi	80.00	119.4	39.4	93.78	8.50
Sansu	77.60	115.9	38.3	94.44	10.08
GCS	78.20	113.2	35.0	94.44	9.35
KMS	81.70	116.0	34.3	94.46	8.70
Total	77.38	116.13	36.8	94.28	9.11

4.2.2 Noise measurements from surface mining activities

Of a total of 70 SPL measurements made at the seven (7) different workshops in the mine using the mini-Sound Level Meter, the A-weighted noise levels recorded during these period were; mean Minimum level of 76.9±3.42dB (A), mean Maximum level was 96.47 ± 5.88 dB (A) and the mean level of 87.63 ± 5.89dB (A).

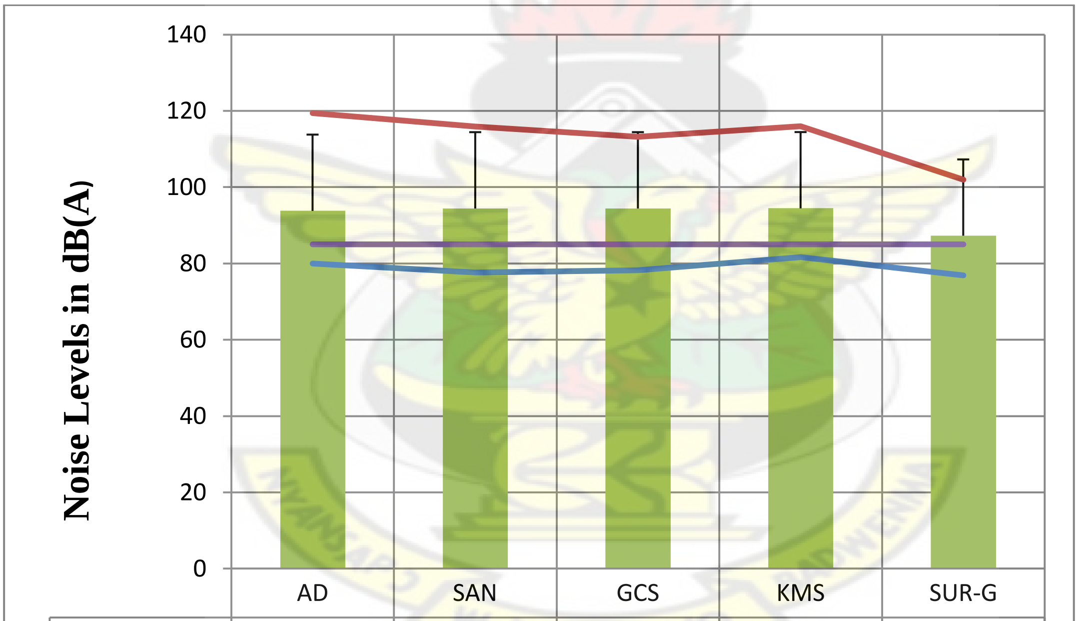
Table 6: Sound Pressure Level from different surface mining activities

SPL	Minimum	Maximum	Range	Mean	Stand Dev
Carpentry	85.88	101.98	16.1	92.84	6.75
Plate Shop	81.98	87.62	5.64	84.27	2.02
Power Station	78.22	99.76	21.54	85.10	7.97
Raise Bore Sp	79.84	92.30	12.46	83.72	5.71
Machine Shop	76.90	95.44	18.54	86.88	6.66
STP	85.20	101.26	18.06	91.57	7.28
TTP	79.14	91.40	11.8	85.38	4.87
Total	76.90	96.47	14.88	87.31	5.89

Generally, the noise levels were substantially high particularly within the underground mining environment. On the average, sound pressure level at the mines was (i.e. underground and surface) 92.5 ± 9.00dB (A). This exceeds the NIOSH Recommended Exposure Level (REL) of 85dB (A).

4.3 Operational shafts

The Results on the SPLs in each operating shaft are shown in Figure. 5. The operating shafts in the mines are the functioning shafts each of which can also boost of all the activity areas. For the purpose of analysis, Surface General (SUR-G) which comprises of workshops and the processing plants were also considered an operating shaft.



	AD	SAN	GCS	KMS	SUR-G
Mean	93.8	94.44	94.44	94.46	87.3
Minimum	80	77.6	78.2	81.7	76.9
Maximum	119.4	115.9	113.2	116	101.98
Standard	85	85	85	85	85

Figure 5: Mine Wide Operational shafts Personal Noise Exposure Profile

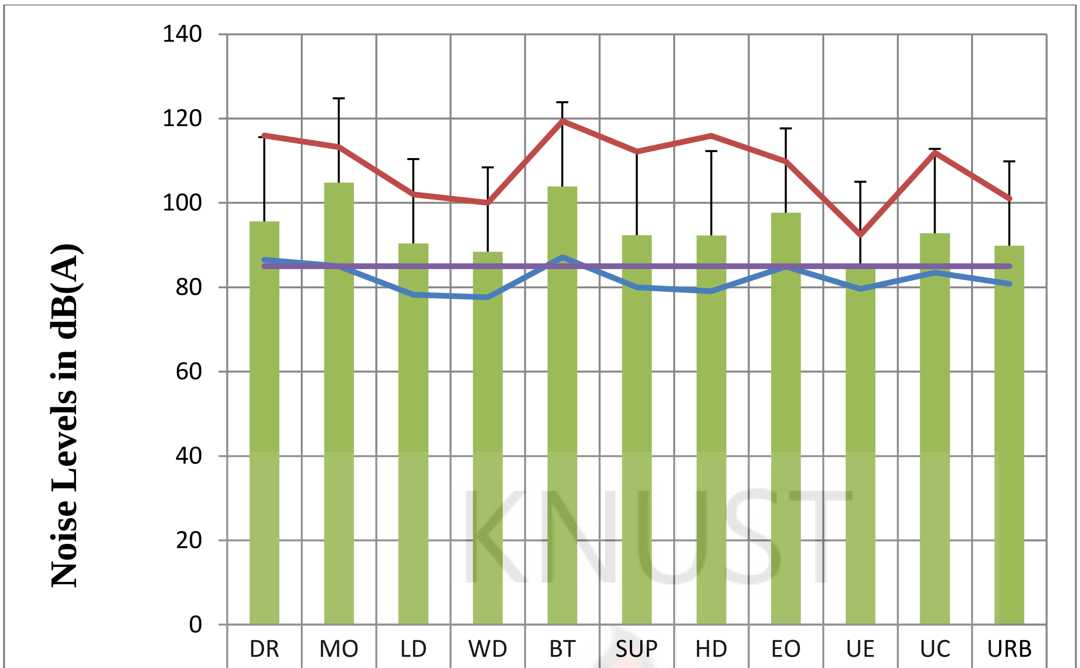
Figure 5 indicates that, the operating shaft with highest minimum noise level was that of KMS whilst Surface General (SUR-G) recorded the lowest minimum noise level of 76.9dB (A). The average SPL emitted from all the operating shafts was above the NIOSH REL of 85dB (A), which may be considered hazardous.

Figure 5 again shows that all the mean levels except one were considerably above the standard of 85dB (A). However, one sample i.e. surface general (SUR G) was close to the standard. The comparison of the means from the operational shafts with the standard did show a statistically significant difference ($P = 0.004$).

As expected, it appeared that, the maximum values of noise exposure for the operating shafts were similar except for surface general which had the lowest of 101.98dB (A). There is no statistically significant difference between the mean maximum (L_{max}) noise levels from the operational shafts and the ACGIH recommended limit of 115dB (A) (t-test, $P < 0.05$).

4.4 Occupation types

The second specific-aim of the study was to determine whether the occupation type of the subjects influenced the SPL and if so to what extent. Figures 6 and 7 represent the noise levels obtained from the eighteen (18) different occupation types found underground and on surface, respectfully. Results indicate that the noise levels differed according to the occupation types (Figures 6 and 7).



	DR	MO	LD	WD	BT	SUP	HD	EO	UE	UC	URB
Mean	95.59	104.8	90.39	88.43	103.9	92.37	92.29	97.67	85.01	92.81	89.85
Minimum	86.5	85	78.2	77.6	87.1	80	79.1	84.9	79.6	83.5	80.8
Maximun	116	113.2	102	100	119.4	112.2	115.9	109.8	92.4	111.9	101
Standard	85	85	85	85	85	85	85	85	85	85	85

Figure 6: Noise Exposure Profile of Underground occupational types only

4.4.1 Noise Exposure; Underground occupational types only

In comparing the minimum, mean and maximum noise levels to the National Institute of Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of 85dB (A) for occupational noise exposure for 8 hours average SPL, the mean minimum for Driller (DR) and Blast man (BT) were slightly above the standard by 1.5dB (A) (less than 2%) and 2.1dB (A) (about 2.4%) respectively. The mean minimum for Machine Operator (MO) was found equal to the standard. The mean minimum noise levels of Loco Drivers (LD), Welders (WD), Supervisor (SUP) and Headman (HD) were determined to be similar (Figure 6).

All the mean SLP values of the underground occupations did exceed level of Time Weighted Average (TWA) of 85dB (A) which may be considered hazardous.

The Machine Operators (MO) recorded the highest mean of 104.8dB (A) which was followed closely by the Blast man (BT) with a mean of 103.87dB (A). As expected, a similarity was observed between the means of Supervisor (SUP) and Headman (HD). However, only electrician (UE) had a mean slightly above (i.e. less than 1%) the NIOSH REL of 85dB (A).

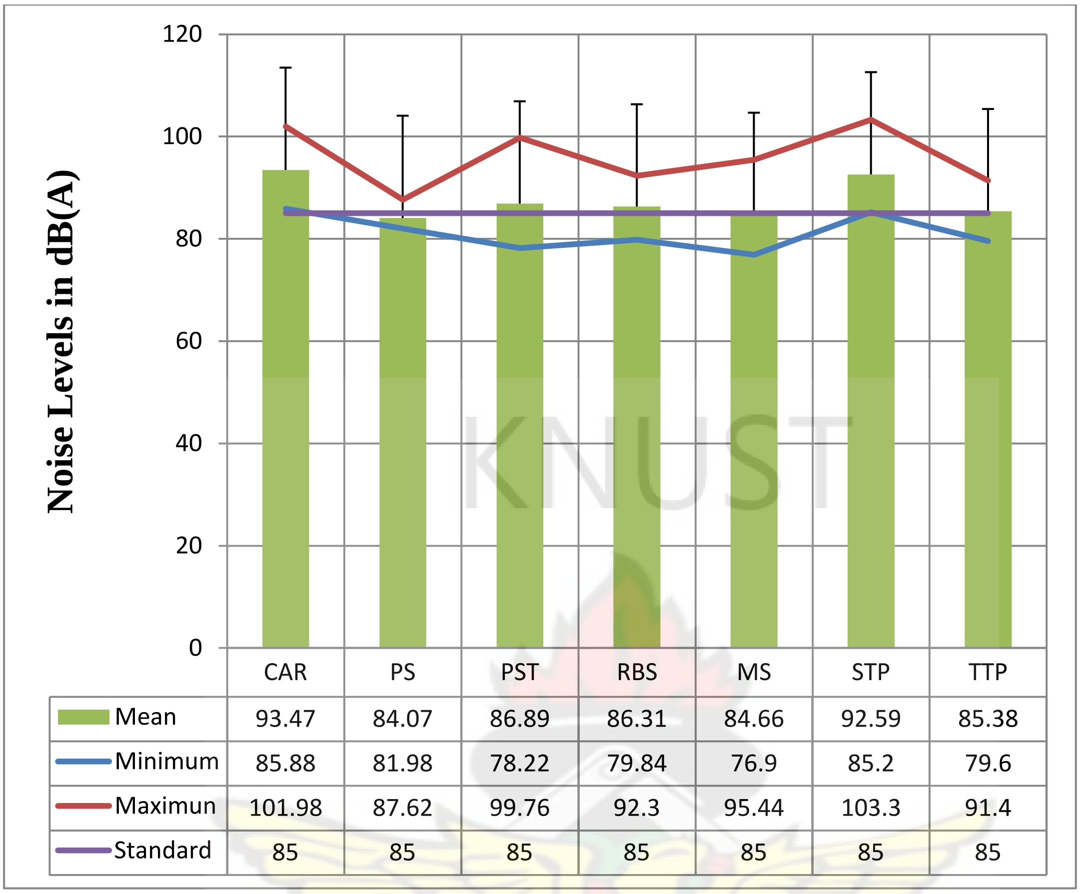
Furthermore, 3 (27.3%) noise levels exceeded the American Conference of Governance Industrial Hygienists (ACGIH) Recommended Threshold Limit Values (TLVs) for maximum level of 115dB (A). The highest maximum level of 119.4dB (A) was recorded by Blast man (BT) with electrician (UE) recording the lowest maximum of 92.4dB (A). The comparison of the mean SPLs ($L_{Aeq.8hrs}$) from the underground occupational types with the standard showed a statistically significant difference (t-test, $P < 0.05$).

4.4.2 Noise Exposure; Surface occupational types only

Results on the minimum, maximum and mean SPL of surface miners are shown in Figure 7. Two of the minimum sample measurements were above the standard by 1.04% and 0.2% respectively. However, most minimum measurements of surface miners were between 78.2 and 85.88dB (A). Furthermore, Carpenters (CAR) recorded the highest mean of 93.37dB (A) with the lowest of 84.07dB (A) were recorded at the Power Station workers workshop (PST). Machine Shop Workers (MS) had a mean slightly below the recommended level of 85dB (A).

With regards to the maximum, all the sample measurements were above the standard of 85 dB (A). The comparison of the means from the surface occupational types with the standard did show a statistically significant difference ($P = 0.002$).

Generally, all the occupational types were susceptible to noise levels which were potentially harmful, however, Drillers (DR), Machine Operators (MO), Blast men (BT), Carpenters (CAR) and STP workers were especially susceptible to noise levels which are potentially harmful since their minimum noise levels exceed the recommended standard of 85dB (A).



	CAR	PS	PST	RBS	MS	STP	TTP
Mean	93.47	84.07	86.89	86.31	84.66	92.59	85.38
Minimum	85.88	81.98	78.22	79.84	76.9	85.2	79.6
Maximun	101.98	87.62	99.76	92.3	95.44	103.3	91.4
Standard	85	85	85	85	85	85	85

Figure 7: Noise Exposure Profile of Surface occupational types only

4.5 Noise prolife levels of activity areas

Based on the various underground occupation types that were grouped into five activity areas with each performing a unique function, the minimum noise levels obtained from all the activity areas were below 85dB (A). The highest minimum noise level was obtained by Shaft & Service (S&S) recording 82.1dB (A). This value was not significantly different from the value of 77.6dB (A) recorded for Development (DEV) which was also the lowest minimum sound pressure level.

The results of the mean are represented in Figure 8. The highest mean of 97.13dB (A) (14% > 85) was obtained by Development (DEV) with the lowest of 90.14dB (A) (6% > 85) being the mean value observed for Underground Roving (UR).

With regards to the maximum noise level, the highest maximum of 119.4dB (A) recorded for Haulage (HL) was significantly different from 110.1dB (A) observed for Underground Roving (UR) which was also the lowest. Development (DEV) and Stope (ST) had very similar maximum values with a minimal difference of 0.17dB (A). The comparison of the means from the activity areas with the standard did not show a statistically significant difference (t-test, $P < 0.05$).

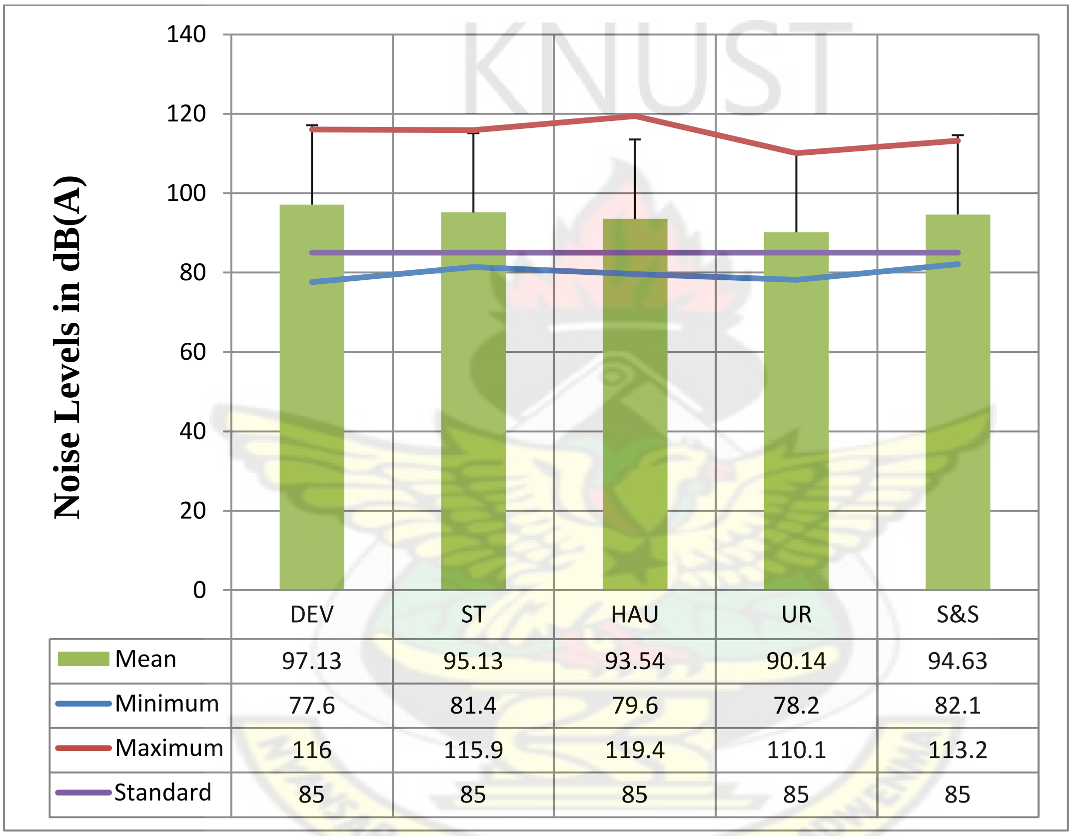
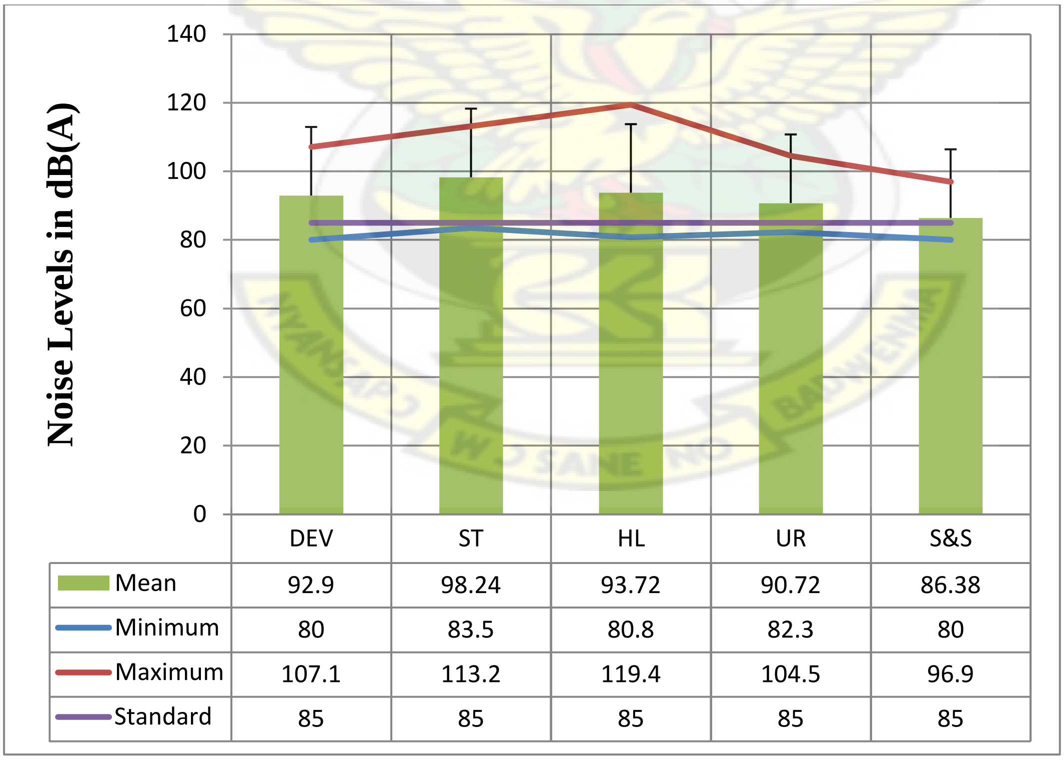


Figure 8: Mine Wide Activity Areas Personal Noise Exposure Profile

4.5.1 Adansi shaft noise profile levels

The conventional approach to segmenting the work force for noise exposure monitoring is based on Homogeneous Exposure Group (HEG), sampling areas, activity areas and occupation. Figure 9-12 present the respective SPLs for the different activity areas in each operating shaft. Figure 9 indicates that, the mean minimum of all the activity areas obtained from Adansi were below 85dB (A). With reference to the mean, the 'noisiest' activity area was Stope (98.24 ± 7.27dB (A)) and the 'quietest' area was Shaft & Service (86.38 ± 6.37db (A)). There was a significant difference in the values obtained between Shaft and Services (S&S) and the other activity areas.

Only (20%) measurement exceeded the ACGIH recommended limit TLVs for maximum level 115dB (A)) as shown in figure 9. There was no statistical significant difference between mean maximum values and the standard of 115dB (A) (t. test $P < 0.05$).



	DEV	ST	HL	UR	S&S
Mean	92.9	98.24	93.72	90.72	86.38
Minimum	80	83.5	80.8	82.3	80
Maximum	107.1	113.2	119.4	104.5	96.9
Standard	85	85	85	85	85

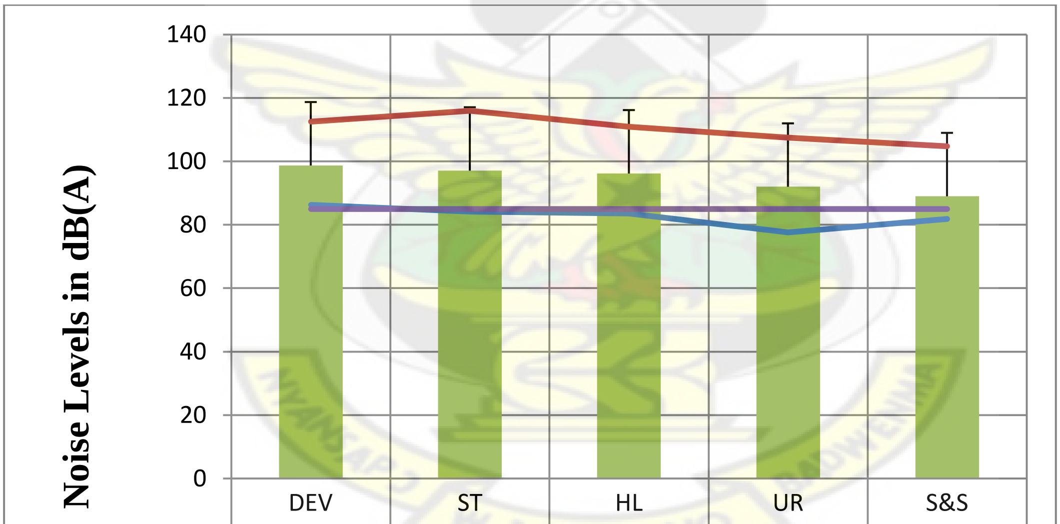
Figure 9: Noise exposure levels of activity areas in the Adansi shaft

4.5.2 Sansu shaft noise profile levels

Figure 10 shows the results of work shift dosimeter measurements. Development (DEV) recorded the highest mean minimum of 86.3dB (A) which was a little above 85dB (A). The difference was not statistically significant. The lowest value of 77dB (A) was recorded for Underground Roving (UR), about 8.7% below the standard of 85dB (A).

All the mean values from the respective activity areas in Sansu did exceed levels of TWA of 85dB (A) which may be considered hazardous. The comparison of the means from the Sansu shafts with the standard did show a statistically significant different (P value = 0.006).

All maximum values were considerably distant from the standard. Stope was further isolated from the rest of the activity areas since it recorded the highest maximum value of 115.9dB (A) which also was beyond the ACGIH maximum standard of 115dBA.



	DEV	ST	HL	UR	S&S
Mean	98.7	97.07	96.17	91.99	88.99
Minimum	86.3	84.2	83.6	77.6	81.8
Maximum	112.5	115.9	110.9	107.5	104.7
Standard	85	85	85	85	85

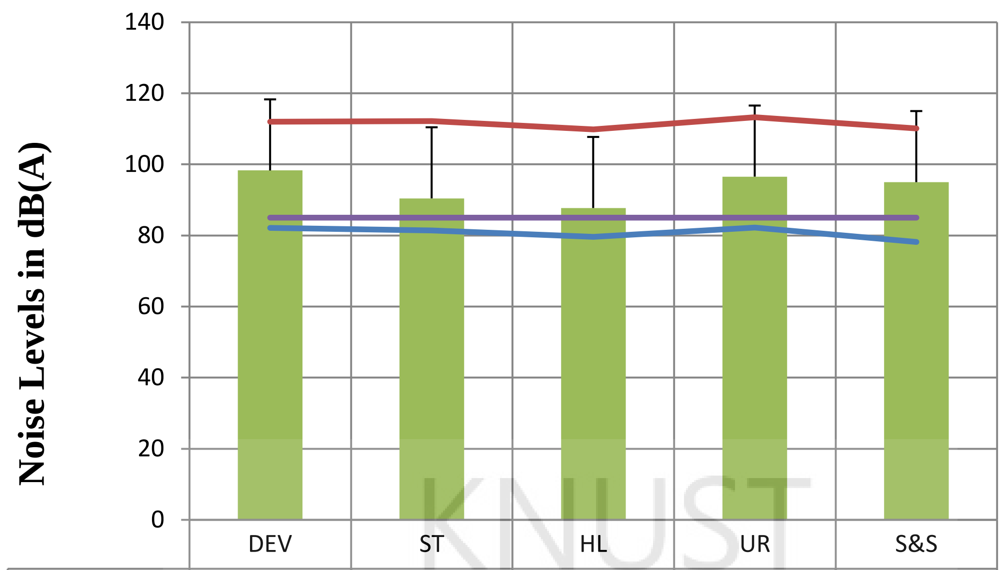
Figure 10: Noise exposure levels of activity areas in the Sansu shaft

4.5.3 George Cappendel shaft noise profile levels

Figure 11 shows that, all measurement of maximum personal noise exposure from GCS were between 109.8 and 113.2dB (A). The maximum values of Haulage (HL) and Shaft& Service (S&S) were similar. These two areas were also slightly lower than Underground Roving (UR) which recorded the highest maximum noise level of 113.2dB (A). T-test indicated statistically significant difference between the maximum noise levels for all GCS miners and the standard (t-test P = 0.006).

Again the average Sound Pressure Level ($L_{Aeq.8hrs}$) based on the activity areas in GCS varies from 87.7 to 98.3dB (A). The highest noise area was Development (98.3 $\pm$ 8.5dB (A)) with Haulage (HL) which was slightly above the acceptable limit by 3.2% being the least noise area recording the lowest mean of 87.7dB (A). The $L_{Aeq.8hrs}$ of the noise dosimeter measurements indicated statistically significant difference of $L_{Aeq.8hrs}$ exceeding 85dBA (t-test, $P < 0.05$).

With respect to the minimum, Underground Roving (UR) recorded the highest value, followed by development (DEV), then haulage (HL) with Shaft & Service (S&S) recording the lowest. The minimum values were clearly below the standard of 85dB (A).



	DEV	ST	HL	UR	S&S
Mean	98.27	90.42	87.7	96.53	94.98
Minimum	82.1	81.4	79.6	82.2	78.2
Maximum	112	112.2	109.8	113.2	110.1
Standard	85	85	85	85	85

Figure 11: Noise exposure levels of activity areas in the George Cappendel Shaft

4.5.4 Kwasi Mensah shaft noise profile levels

The results in Figure 12 indicate that the maximum values differ according to the activity area. Development (DEV) recorded the highest maximum value which is also slightly above the recommended maximum limit of 115dB (A). This was closely followed by Underground Roving (UR) with Stope (ST) obtaining the lowest maximum of 105.9dB (A).

With respect to the mean, Development (DEV) and Underground Roving (UR) had very similar mean values, which are 98.7 and 97.98 dB (A) respectively. The mean values for Stope (ST) and shaft & Service (S&S) were similar with 0.83dB (A) noted as the difference between them. There was a significant difference between the mean values of development and Shaft & Service. In summary, the mean values of personal noise exposure from these activity areas were considerably higher than the REL of 85dB (A).

All but two (Haulage and Underground Roving) of the data measurements were found to be below the NIOSH REL. Figure 12 shows that Underground Roving recorded the highest minimum of 87.8dB (A) (3.3% above 85dB (A)) with the lowest minimum SPL of 81.7dB (A) (3.3% below 85dBA)) observed for Stope.

In general, 20% measurements exceeded the ACGIH Recommended limit TLVs for maximum level 115dB (A). The comparison of the mean maximum noise levels from the activity areas at KMS with the standard did show a statistically significant difference (P = 0.002).

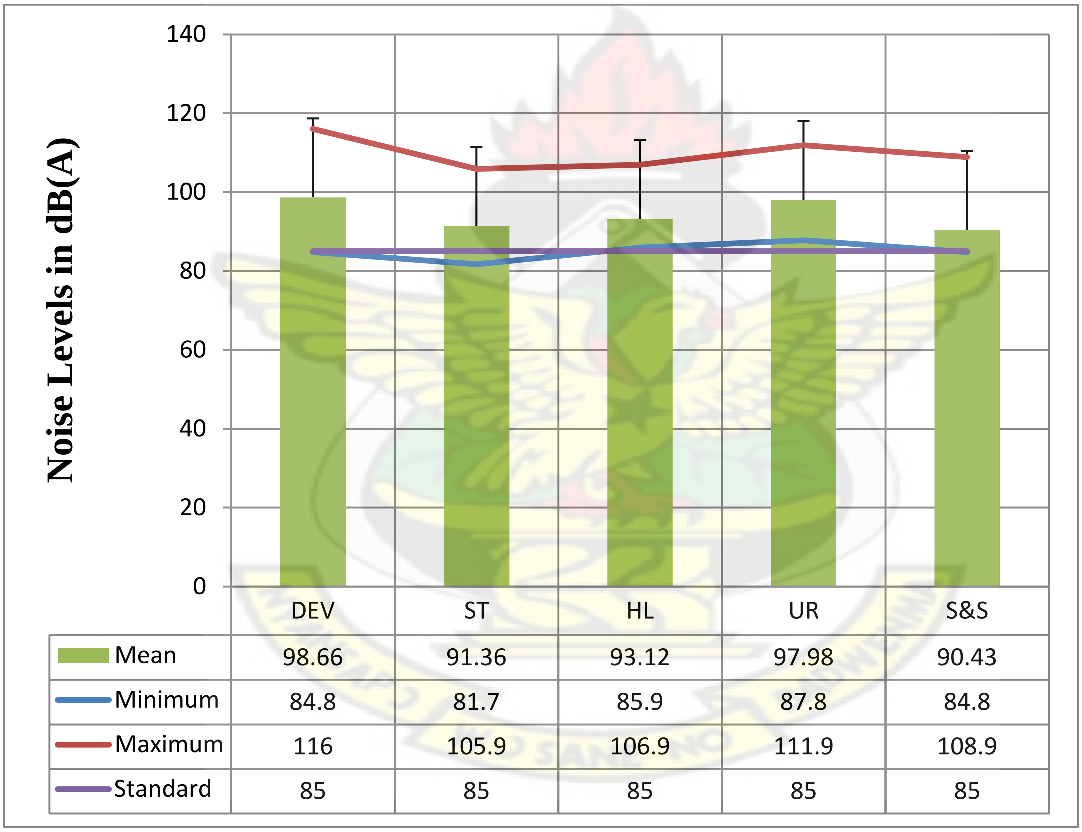


Figure 12: Noise exposure levels of activity areas in the Kwasi Mensah Shaft

4.6 Sound pressure levels from workshops

Noise measurements obtained from the Carpentry (CAR), Plate Shop (PS), Power Station (PST), Raise Boring (RBS), Machine Shop (MS) and Sulfide Treatment Plant (STP) and

Tailing Treatment Plant (TPT) which were at different locations in the mines are presented in figure 14–20 respectively. All workshops visited have different production units with different types of machines.

4.6.1 Mean sound pressure levels from Carpentry

Figure 13 displays the average noise levels obtained from the machines in the carpentry shop compared to the NIOSH REL standard of 85dB (A). The measured values ranged between 85.6 - 101.98dB (A) with 92.8$\pm$6.04dB (A) recorded as the average sound pressure level. This demonstrates that the noise levels produced by these machines exceed the limiting threshold level of 85dB (A). Among all the machines studied from this shop, the Chain-Saw Machine (CSM) was found to emit higher decibel value with mean 101.98dB (A). However, there was no significant difference between the mean value obtained and the standard of 85dB (A) (t-test $P < 0.05$).

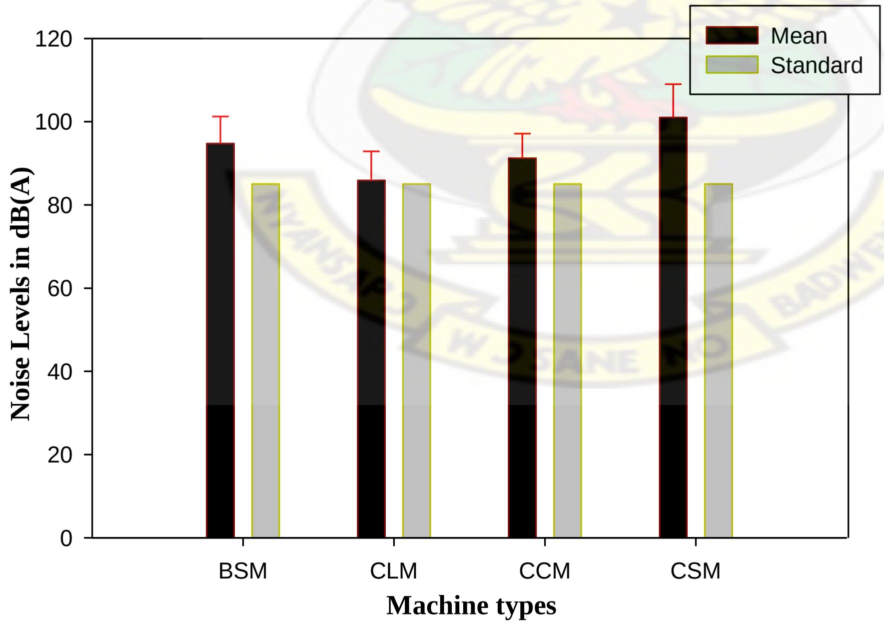


Figure 13: Sound Pressure Levels from Carpentry Shop

4.6.2 Mean sound pressure levels from Plate Shop

The noise levels emitted from machines at Plate Shop is illustrated in Figure 14. All the mean values except the Saw-Cutting Machine (SCM) was below the acceptable level of 85dB (A). In summary, the average noise level obtained was 84.27 $\pm$ 2dB (A). There was a significant difference in the mean values obtained from the workshop and the standard of 85dB (A) (t-test P = 0.024).

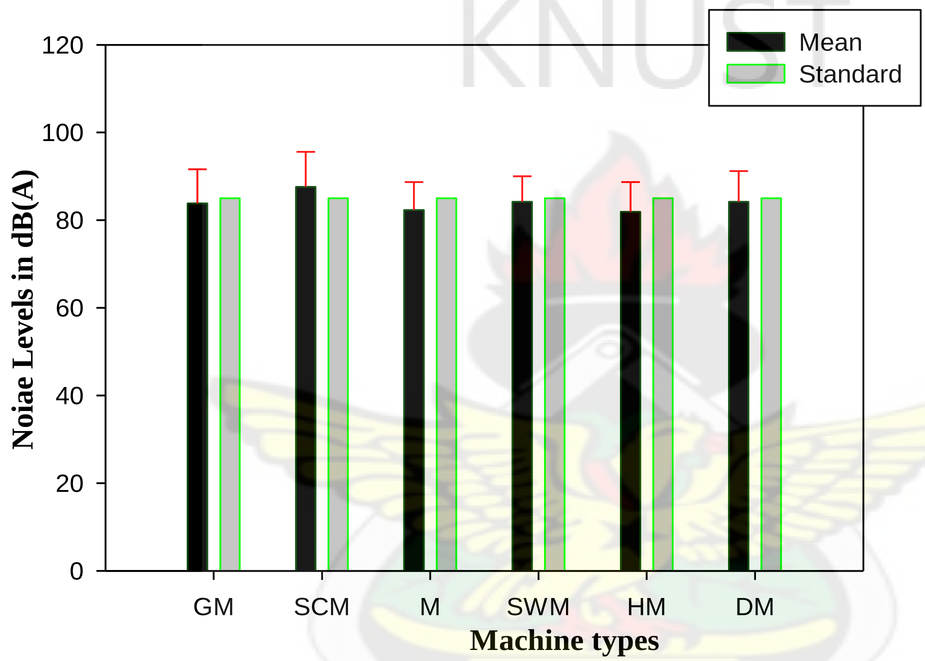


Figure 14: Sound Pressure Levels from Plate Shop

4.6.3 Mean sound pressure levels from Power Station

Figure 15, presents the noise levels obtained from the Power Station. The noise levels ranged between 78.2 – 99.7dB (A). Centex Compressor (CC) emanated higher decibel value with Primary Water Pump (PWP) being the least noise emitting machine recording a mean of 78.2dB (A). In summary, the comparison of the mean values and recommended level of 85dB (A) did show statistically significant difference (P value = 0.025).

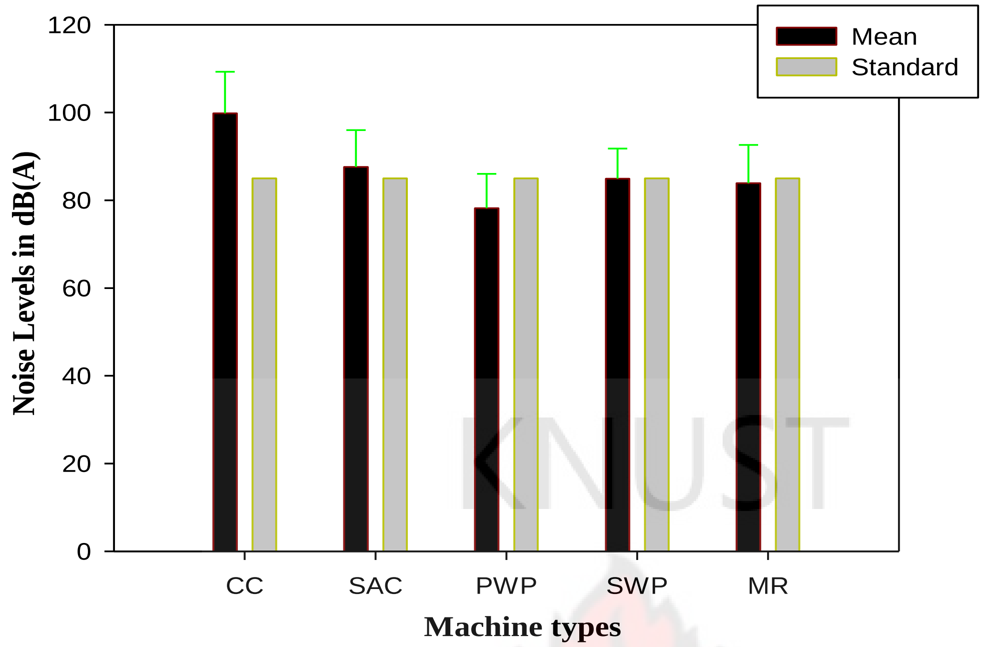


Figure 15: Sound Pressure Levels from Power Station

4.6.4 Mean sound pressure levels from Machine Shop

According to Figure 16, the highest mean was obtained by the Grinding Machine (GDM) recording a mean value of 95.4dB (A). This was significantly different from 76.9dB (A) recorded for the Lathe Machine (LM) which was the lowest value. In summary, the average SPL from the machine shop was 83.75±5.93dB (A) which is considered hazardous.

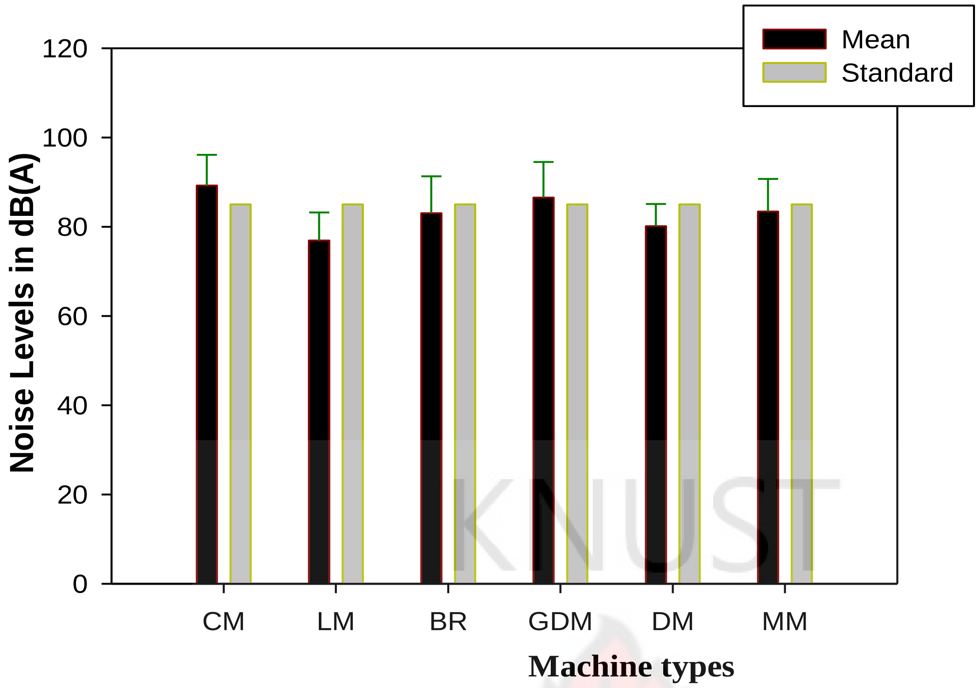


Figure 16: Sound Pressure from Machine Shop

4.6.5 Mean sound pressure levels from Raise Boring Shop

The average Sound Pressure Level ($L_{Aeq.8hrs}$) emitted from the Raise Boring Shop was 85.99± 5.23dB (A). From Figure 17, it can be seen that, the highest noise emitting machine was Alimak (ALI) whilst the lowest noise level of 79.8dB (A) was recorded for Diamec Machine (DMM).

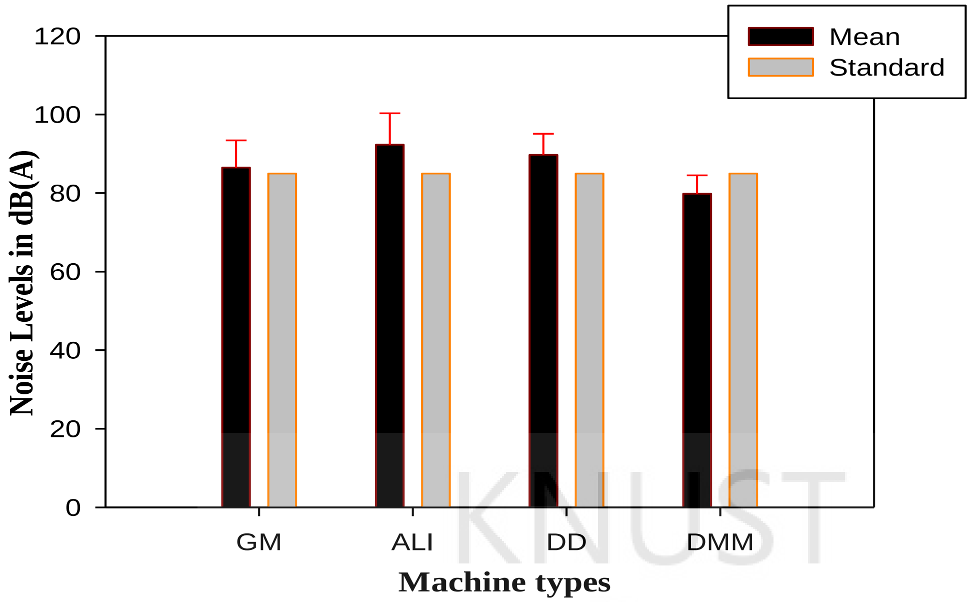


Figure 17: Sound Pressure Levels from Raise Boring Shop

4.6.6 Mean sound pressure levels from STP and TTP

Figure 18 presents noise levels obtained from Sulfide Treatment Plant (STP) whilst figure 19 shows the values of the measured noise levels in the Tailing Treatment Plant (TTP). The noise levels measured in the STP ranges between 103.4 - 85.2dB (A) with 91.58±6.65dB (A) being the mean noise level. On the other hand, mean measured value in TPT was 85.84dB (A) which was slightly above (less than 1%) the NIOSH REL of 85dB (A). The comparison of the means from the processing plants with the standard of 85 dB (A) did show a statistically significant difference (t-test $P < 0.004$).

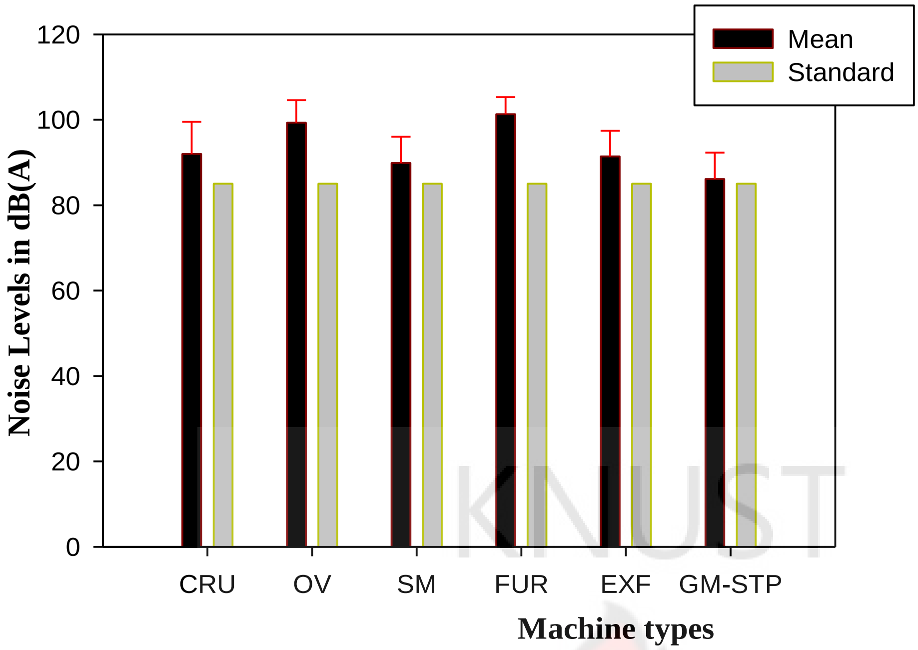


Figure 18: Sound Pressure levels from Sulfide Treatment Plant

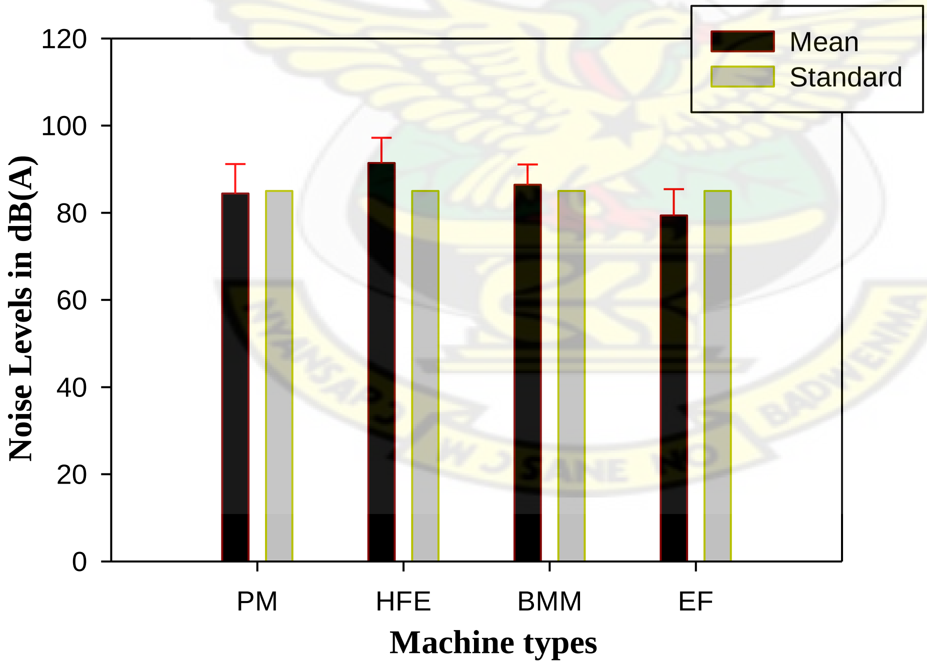
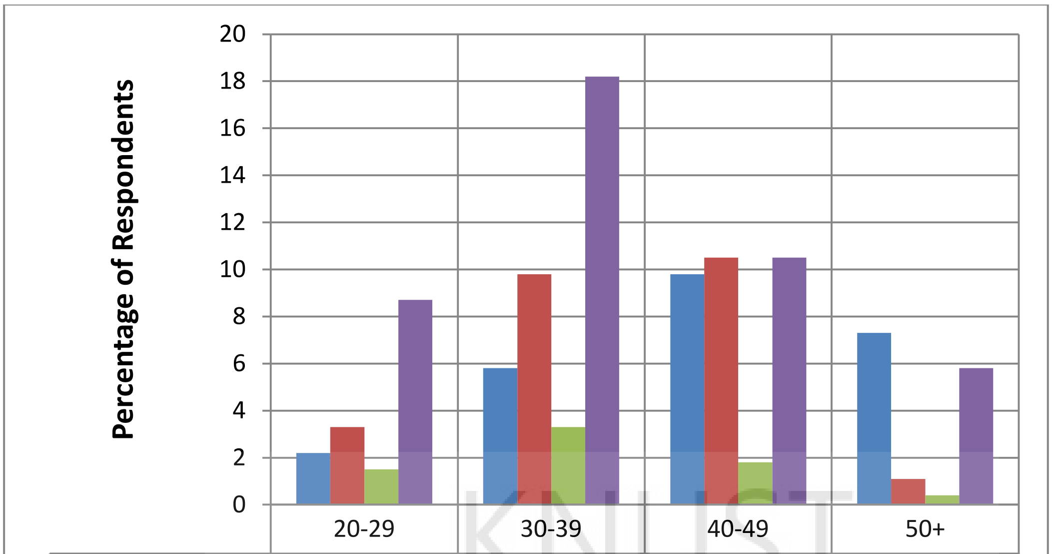


Figure 19: Sound Pressure Levels from Tailing Treatment Plant

4.7 The incidence of tinnitus

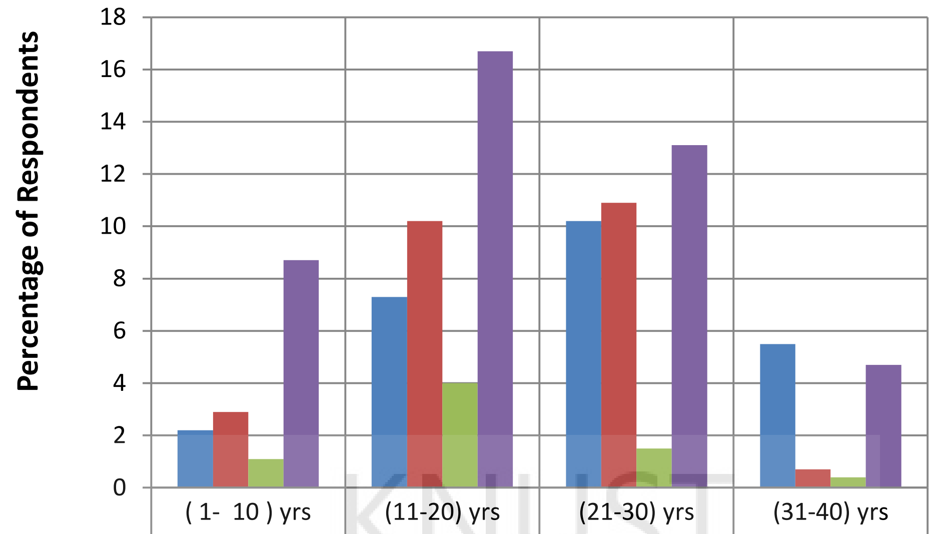
Tinnitus is a physical condition, experienced as noises or ringing in the ears or head when no such external physical noise is present. Tinnitus is usually caused by a fault in the hearing system; it is a symptom, not a disease in itself. It is as a result of prolong exposure to noise. Figure 20 indicates that the majority of tinnitus sufferers were in the age range 40 - 49 years.



	20-29	30-39	40-49	50+
Yes, Always	2.2	5.8	9.8	7.3
Yes, Sometimes	3.3	9.8	10.5	1.1
Yes, Occasionally	1.5	3.3	1.8	0.4
No, Never	8.7	18.2	10.5	5.8

Figure 20: Age and the prevalence of tinnitus

The way that one interprets whether or not a miner suffers from tinnitus will determine how to read the results of this study. If one assumes that the answers ‘yes always’, ‘yes sometimes’ and ‘yes occasionally’ all mean that the subject suffers from the effects of tinnitus, then the results from these categories must be added together to ascertain the incidence of tinnitus in gold mining population. Working on this assertion, the study found that tinnitus was present in 48% of miners below 50 years old, while in subjects over 50 years of age the incidence was 8.8%.



	(1- 10) yrs	(11-20) yrs	(21-30) yrs	(31-40) yrs
Yes, Always	2.2	7.3	10.2	5.5
Yes, Sometimes	2.9	10.2	10.9	0.7
Yes. Occasionally	1.1	4	1.5	0.4
No, Never	8.7	16.7	13.1	4.7

Figure 21: Years of service and prevalence of tinnitus in gold mining workers.

The present study found that those who had worked for between 21 and 30 years had the highest symptoms of tinnitus namely 22.2%. It was observed that the group with up to ten (10) years had an incidence of 6.2% and in the group with exposure for 11-30 years it was 44.1%.

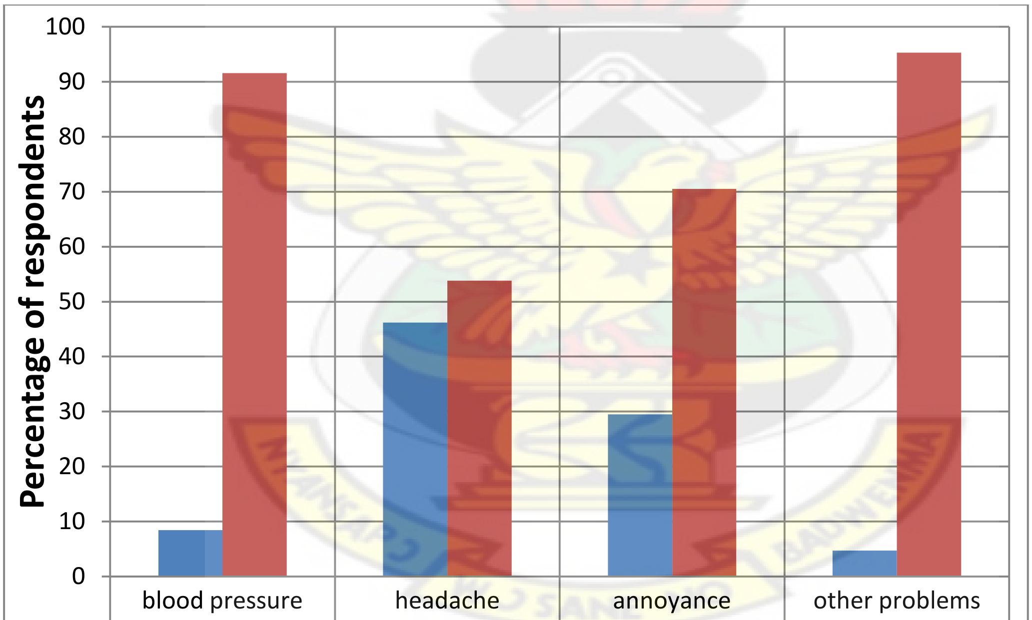
Table 7: The incidence of tinnitus (%) in different occupation types of gold miners

Occupation	Yes, Always	Yes, Sometimes	Yes, Occasionally	No, Never
Driller	25.0	10.0	25.0	40.0
Machine Operator	20.0	30.0	5.0	45.0
Loco Driver	25.0	20.0	10.0	45.0
Welder	30.0	35.0	5.0	30.0
Blast man	40.0	35.0	5.0	20.0
Supervisor	50.0	20.0	0.0	30.0
Headman	35.0	15.0	5.0	45.0
Equipment Operator	10.0	40.0	5.0	45.0
Underground Electrician	6.7	20.0	0.0	73.3
Underground Carpenter	6.7	26.7	13.3	53.3
Underground Raise Borer	13.3	40.0	0.0	46.7
Carpenter	40.0	20.0	0.0	40.0
Plate Shop Worker	20.0	20.0	0.0	60.0
Power Station Worker	40.0	20.0	10.0	30.0
Raise Boring Shop	20.0	30.0	10.0	40.0
Machine Shop Worker	10.0	20.0	10.0	60.0
STP Worker	30.0	10.0	10.0	50.0
TPT Worker	20.0	20.0	10.0	50.0

Table 7 indicates that the occupation type with the highest incidence of tinnitus is that of the Blast man. More than half of the Blast men together with Welders coupled with Supervisors in this population exhibited high symptoms of tinnitus. The population that had the lowest incidence of tinnitus was that of Underground Electricians. Machine shop workers and STP workers also had low incidence of tinnitus. If one assumes that an answer of 'yes always', 'yes sometimes' and' yes occasionally' indicates that miners suffer from the effects of tinnitus, then, more than 50% in almost all occupation types suffered from tinnitus.

4.6.1 Incidence of high blood pressure, headaches and annoyance.

Figure 22 indicates that high blood pressure, headaches, annoyance and other problems were not experienced by 77% of the miners sampled. 8.4 % experienced high blood pressure problems with 46.2 % experiencing headaches. These non-auditory effects of NIHL in gold miners may be a contributing factor to the disability experienced by the miners.



	blood pressure	headache	annoyance	other problems
Yes	8.4	46.2	29.5	4.7
No	91.6	53.8	70.5	95.3

Figure 22: Incidence of high blood pressure, headaches and annoyance symptoms in gold miners.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Underground miners

Based on the measurements it was found that underground miners are exposed to noise levels well above the threshold limit of 85dB (A) especially for the mean level of noise emitted by the heavy mining equipments. On the average, mean continuous equivalent Level, $L_{Aeq.8hrs}$ at the underground area was 94.28 $\pm$ 9.11dB (A) which may be considered hazardous.

The main fan to evacuate stagnant and warm air was one of the major sources of noise in underground mining environments. Axial flow fans (a component of the main fan) with capacity of 400,000 to 700,000 cfm discharges a substantial amount of air. Moving these air volumes requires large power input which are ultimately converted to noise because of inefficiencies inherent in any mechanical system. The noise in the fan system contains components from various sources, including aero dynamic noise from the fan blade causing noise, unbalanced bearing noise, motor noise and gear noise. Control measures like provision of inlet and discharge silencers, noise absorbing splitters and speed control can be adopted (Chattomba, 2010).

Auxiliary fans which are also found in underground and are usually suspended close to the ear level produce higher levels of noise. The noise stems from motor and from air turbulence, mainly at the intake end. Vibrations transmitted from the fan housing to the duct radiates as noise. The suspension of the fans also oscillates to produce noise. Air intakes may be fitted with silencers containing synthetic fiber sound absorption material noise which can reduce noise by as much as 11dB (A) (Chattomba, 2010).

Figure 8 indicates that drillers who usually work at the Development and Stope ends were exposed to higher decibels. The higher decibels were emitted at jack hammer drill, Down the Hole drill (DTH) and the Long Hole Drill (LHD B7). This is due to the jackhammer and DTH dealing with hard ore drilling rocks, as face dressing or blasting. Also the higher Sound pressure level found at LHD B7 is due to the LHD B7 dealing with hard ore and moving loaded and unloaded ore. The major sources of noise from the LHD B7 are the engines, its intake and exhaust, the cooling fans for engine and the drive train. Control measures that could be adopted are controlling engine speed; ventilation isolation mounts between transmissions and structures.

Furthermore, belt conveyers for transporting materials during crushing and grinding found in underground were also observed to emit noise levels which are above the NIOSH recommended level of 85dB (A). This is due to friction between the conveyer belt material and the ore.

Reports of Sound Pressure Levels from the various operating shafts as illustrated in Figure 5 indicates that, all the Underground operating shafts (Adansi, Sansu, GCS and KMS) produced similar average noise levels which are significantly different from surface general. This is because the underground gold mining environment has specific attributes that could have influence the SPL and ultimately impact on the characteristics of Noise-Induced Hearing Loss. These include the fact that the working environment can be up to two kilometers underground and up to ten kilometers into the mine on a vertical plane. Here, miners work on the rock face for many hours a day, often exceeding the usual 8hrs working day, in the presence of high levels of noise from machinery such as drilling equipments, ventilation equipments and transportation equipments in confined areas which may also impact on the acoustical effects that the noise has on the workers (Franz *et al.*, 1997).

This observation is in agreement with that of Amedofu, *et al.*, (1994) who noted that the noise exposure levels associated with various job types in Ghana gold mining environment have been documented as far exceeding the legislated level of 85dB (A). The research Organization of the Chamber of Mines (South Africa) also reported that underground and surface mining equipments such as jackhammer, air compressor, stoping equipments, developing equipments and equipments for bending, grinding and cutting steel plate, are known to emit noise levels of up to 110dB (A) (Schronoder *et al.*,1980).

5.2 Surface miners

The data on the SPL from the various workshops have shown that the carpentry and Sulfide Treatment Plant areas produced the highest levels of noise in the mines. On the average, noise levels at the carpentry and STP areas were 92.8dB (A) and 91.6dB (A) respectively. Power Station, Machine Shop and TTP recorded levels slightly above the standard of 85dB (A). These results further showed that workers in the Processing, Machine Shop and Power Station areas are equally at risk for NIHL as their counterparts in the carpentry shop.

This observation in the carpentry shop is in agreement with that of Adjei and Kunfaa (2007) who found that the operations of the wood processing industries are generally associated with high levels of occupational hazards with consequent health risks. Their study was to assess the perceived occupational health hazards exposure and the effect of the policies put in place to ensure the health and safety of workers in 14 randomly selected wood processing industries at Asokwa, Ahensan and Kaasi in Kumasi.

From Figure 18, it was found that higher decibels were recorded at Crushers, Furnace and Oven. This was due to the high horsepower and the friction between the crusher material and the ore. With regards to the Furnace and the Oven, Axial flow fans with discharge capacity 2lakh ft^3 /min of air with fan static pressure ranging up to 15 cm of water gauge or more. Moving these large air volumes requires large power input which are ultimately converted to noise because of inefficiencies inherent in any mechanical system. Control measures like provision of inlet and discharge silencers, noise absorbing splitters, replacing worn out parts and planned maintenance should be adopted to reduce the noise levels to which miners are exposed. Again, Centex Compressor at the Power Station was found to emit hazardous noise levels because of its large horsepower.

Most report on the etiology of tinnitus are that, the most common cause of tinnitus is NIHL but there is large variability in the reported incidence that range from 5% - 8% (Dancer, 1992). Dancer (1992) found an incidence of 21 - 22% in NIHL subjects under 60% years old, while subjects over 60 years old had an incidence of 33%. Axelsson and Barrenas (1992) cited by Dancer (1992) found that 54 - 58% of miners suffered from tinnitus. Working on the assumption adopted for this study, tinnitus was found in 48% of subjects below 50 years old, while in subjects over the age of 50 years of age the incidence was 8.8%. This percentage confirms Axelsson's and Barrenas's (1992) findings. The present study found that at the age 40 - 49 there was the highest reported symptom of tinnitus, 22.1%. This is significant in that the worker is very active in his social and working life at this stage and the tinnitus could contribute significantly to communicative difficulties he may experience.

The present study found that those who had worked for between 21 – 30 years had the highest reported incidence of the presence of tinnitus, 22.6%. Dancer (1992) found that the incidence of tinnitus was 34% in a population exposed to noise for up to ten (10) years. After this, the incidence of tinnitus was reasonably constant in the group where exposure was 11-30 years, namely 54%, and in the group exposed for 31 - 50 it was 50%. The present study found that the group with up to ten (10) years of service had an incidence of 6.6%, 11-30 years had an incidence of 44.1% and the group with exposure of 31 -40 years had an incidence of 6.6 %. The difference in the results may be due to different questionnaire methods techniques used in the different studies or may be influenced by noise types in different industries.

The occupation types with the highest incidence of tinnitus were that of the Blast man, Welders and Supervisors with lowest recorded for Underground electricians, Machine Shop workers and Power Station Workers. Dancer (1992) regards the diversity of results when studying tinnitus and NIHL as being due to the diversity of investigation methods and subjects choices. The significant results from the present study that a large percentage of the subjects suffered from tinnitus to some degree may indicate the need on the part of gold mining industry to take greater precaution in their hearing conservation programmes. Dancer (1992) puts it this way: “NIHL is completely unnecessary condition except for accidental circumstances” and it could be added that tinnitus is completely unnecessary condition.

Axelsson (1992) states, “even if tinnitus is completely subjective, it should be considered in compensation claims, because it frequently increases the total handicap to a considerable extent.” The implication for the audiologist is the importance of including tinnitus retraining or special fitting of hearing aids in the total treatment of the gold miners to ensure that communication health and hearing are achieved.

Finally it is generally known that noise exposure has long been recognized as the major contributors to occupational and non-occupational hearing defects, but a recent finding is that, the effect of noise in the workplace can be exacerbated by other non – acoustic agents, such as extreme temperatures, vibrations and chemicals (Ward, 1995). Thus the interaction of noise and other agents contribute to the large variability observed in a population’s response to the noise exposure and if overlooked may undermine the success of traditional hearing conservation programmes (Morata, 1993).

It is evident from the above findings that occupational noise-level above 85dB (A) is hazardous and could lead to temporal or permanent hearing loss. Therefore, control measures should be adopted in mines for machinery noise reductions as well as hearing protection aids should be supplied to the workers in order to protect the mine workers from NIHL.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

The study shows that miners working underground and in all the operating shafts appear to have been substantially over exposed to noise levels above 85dB (A). The most critical exposure was the average level of sound emitted from equipments such as the compressors, drilling machines, crushers, auxiliary fans and other mechanical machines.

Sound Pressure Levels from all the operating shafts (Adansi, Sansu, GCS and KMS) were similar. The Development and Stope ends were observed to be the noisiest activity areas whilst underground roving was the quietest within the mines. Based on the questionnaires results, majority of the miners (i.e. 56.8%) experienced symptoms of Noise Induced Hearing Loss (NIHL).

Further evaluation of gold miners' ability to hear by audiometric testing may be needed to assess the status of NIHL among workers at AngloGold Ashanti limited.

The control of noise particularly in underground and the various workshops are highly recommended through the implementation of engineering noise control, administrative noise control or the use of hearing protection device that suite with the task during working. Hearing conservation programme should be established to prevent the risk of NIHL. The setting up of a database for all workers and the records of their pre-employment hearing thresholds, their annual hearing screening and any further diagnostic audiology testing would also be a helpful tool in controlling the hearing conservation programmes.

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APPENDICES

APPENDIX A

EMPLOYEE HISTORY QUESTIONAIRE

PREVIOUS EMPLOYEE	YRS. OF SERV.	OPERATING SHAFT	ACTIVITY AREA	TINNITUS INCIDENCE		EAR PROTECTION	
				YES	NO	YES	NO

Sampling area……………. Activity area……………….. Occupation…………………..

Age …………… Gender ……………….. Years of service ……………….

ASSESSMENT OF NOISE EXPOSURE AMONG MINERS AT ANGLO GOLD ASHANTI LIMITED (OBUASI)

The following questions focus on the exposure to hazardous sounds. Please answer all of the questions carefully and to the best of your ability. Please be specific as possible as you can.

1. Have you ever served in the military?

☐ Yes ☐ No

2. Have you ever served in other security service?

☐ Yes ☐ No

3. Have you ever had any of the following?

YES	NO		IF YES, WHICH EAR		
			LEFT	RIGHT	BOTH
☐	☐	HEARING LOSS	☐	☐	☐
☐	☐	EAR SURGERY	☐	☐	☐
☐	☐	EAR ARCHES	☐	☐	☐
☐	☐	EAR INJURY	☐	☐	☐
☐	☐	HEAD INJURIES	☐	☐	☐

4. Have you ever been diagnosed/had a problem with any of the following?

YES NO

☐ ☐ HIGH BLOOD PRESSURE

☐ ☐ HEADACHES

☐ ☐ ANXIETY

☐ ☐ ANNOYANCE/IRRITATION

5. Have you being experiencing ringing or other noises in the ears?
- Yes; Always ☐ ☐ No; Never
- Yes; Sometimes ☐
- Yes; Occasionally ☐

If yes, when does it occur...……………………………………………………………………..

6. Do you have trouble hearing your colleagues in the working environment?
- Yes; Always ☐ ☐ No; Never
- Yes; Sometimes ☐
- Yes; Occasionally ☐

Please describe in what situation(s) you have problems hearing your colleagues:

………………………………………………………………………………………………

7. Do you have trouble hearing friends and relatives after working hours?
- Yes; Always ☐ ☐ No; Never
- Yes; Sometimes ☐
- Yes; Occasionally ☐

8. Do you have problems with any of the following from tour working environment?

i. Ototoxic chemicals
ii. High temperature
iii. Vibrations **(circle as appropriate)**

9. Have you ever had routine exposure to noise during your mining work schedule?
- Yes
- No

On the average, I am exposure to noise of ………… mins or hrs. .... per session

10. Have you ever had routine exposure to any of the following non-occupational noise sources;

YES NO

☐ ☐ POWER TOOLS

☐ ☐ LOUD MUSIC

☐ ☐ MOTOR CYCLE

☐ ☐ AUTO/WOOD SHOPS

☐ ☐ FIREARMS

11. Do you use hearing protection such as earplugs or earmuffs whenever you are in a noisy working environment?

- Yes; Always ☐ ☐ No; Never
- Yes; Sometimes ☐
- Yes; Occasionally ☐

12. Have you been taught about the effects of hazardous sound on hearing?

- Yes
- No

If yes where did you get the information from?
………………………………………………………..

APPENDIX B

CONFIGURATION OF MEASURING INSTRUSMENTS

The configuration of the mini-Sound Level Meter is as follows:

- Range – 40 – 140dB
- Bandwidth – 1/3 octave
- Peaks over – 140dB
- Time weighting – slow
- Frequency weighting – A
- Logging – 1record/ second

The configuration of the dosimeter is as follows:

- Range – 70 – 140dB
- Time weighting – slow
- Frequency weighting – A
- Frequency weighting for peaks – C
- Exchange rate 3dB
- Threshold – 80dB
- Criteria level – 85dB
- Logging – 1record/second

Casella CEL Dosimeter (dBadge) with Integrated Display.

Mini Sound Level Meter

CEL – 110 / 1 Calibrator

Table 1: Sound Pressure Level of Respondent

Occupation of Respondent	Mean	N	Std. Deviation	Minimum	Maximum
Driller	95.78	20	6.314	86.50	116.00
Machine Driver	104.80	20	8.075	85.00	113.20
Loco Driver	90.39	20	5.597	78.20	102.00
Welder	88.43	20	4.266	77.60	100.00
Blastman	103.87	20	8.544	87.10	119.40
Supervisor	92.37	20	8.401	80.00	112.20
Headman	92.29	20	8.749	79.10	115.90
Equipment Operator	97.66	20	6.106	84.90	109.80
Underground Electrician	85.01	15	3.394	79.60	92.40
Underground Carpenter	92.80	15	9.859	83.50	111.90
Underground Raise Borer	89.84	15	5.968	80.80	101.00
Carpenter	92.83	10	6.042	85.88	101.98
Plate Shop Worker	84.27	10	2.001	81.98	87.62
Power Station Worker	86.88	10	7.517	78.22	99.76
Raise Bore Operator	85.99	10	5.249	79.84	92.30
Machine Shop Worker	83.75	10	5.927	76.90	95.44
STP Worker	91.57	10	6.651	85.20	101.26
TTP Worker	85.83	10	4.591	79.14	91.40
Total	92.50	275	9.008	76.90	119.40

Table 2: Occupation of Respondents in relation to incidence of Tinnitus

			Symptoms of Tinnitus				
			Yes Always	Yes Sometimes	Yes Occasionally	No Never	Total
Occupation of Respondent	Driller	Count	5	2	5	8	20
		% within Occupation of Respondent	25.0%	10.0%	25.0%	40.0%	100.0 %
	Machine Driver	Count	4	6	1	9	20
		% within Occupation of Respondent	20.0%	30.0%	5.0%	45.0%	100.0 %
	Loco Driver	Count	5	4	2	9	20
		% within Occupation of Respondent	25.0%	20.0%	10.0%	45.0%	100.0 %
	Welder	Count	6	7	1	6	20
		% within Occupation of Respondent	30.0%	35.0%	5.0%	30.0%	100.0 %
	Blastman	Count	8	7	1	4	20
		% within Occupation of Respondent	40.0%	35.0%	5.0%	20.0%	100.0 %
	Supervisor	Count	10	4	0	6	20
		% within Occupation of Respondent	50.0%	20.0%	.0%	30.0%	100.0 %
	Headman	Count	7	3	1	9	20
		% within Occupation of Respondent	35.0%	15.0%	5.0%	45.0%	100.0 %
	Equipment Operator	Count	2	8	1	9	20
		% within Occupation of Respondent	10.0%	40.0%	5.0%	45.0%	100.0 %
	Underground Electrician	Count	1	3	0	11	15
		% within Occupation of Respondent	6.7%	20.0%	.0%	73.3%	100.0 %
	Underground Carpenter	Count	1	4	2	8	15

		% within Occupation of Respondent	6.7%	26.7%	13.3%	53.3%	100.0%
	Underground Raise Borer	Count	2	6	0	7	15
		% within Occupation of Respondent	13.3%	40.0%	.0%	46.7%	100.0%
	Carpenter	Count	4	2	0	4	10
		% within Occupation of Respondent	40.0%	20.0%	.0%	40.0%	100.0%
	Plate Shop Worker	Count	2	2	0	6	10
		% within Occupation of Respondent	20.0%	20.0%	.0%	60.0%	100.0%
	Power Station Worker	Count	4	2	1	3	10
		% within Occupation of Respondent	40.0%	20.0%	10.0%	30.0%	100.0%
	Raise Bore Operator	Count	2	3	1	4	10
		% within Occupation of Respondent	20.0%	30.0%	10.0%	40.0%	100.0%
	Machine Shop Worker	Count	1	2	1	6	10
		% within Occupation of Respondent	10.0%	20.0%	10.0%	60.0%	100.0%
	STP Worker	Count	3	1	1	5	10
		% within Occupation of Respondent	30.0%	10.0%	10.0%	50.0%	100.0%
	TTP Worker	Count	2	2	1	5	10
		% within Occupation of Respondent	20.0%	20.0%	10.0%	50.0%	100.0%
Total		Count	69	68	19	119	275
		% within Occupation of Respondent	25.1%	24.7%	6.9%	43.3%	100.0%

Table 3: Age of Respondent in relation to incidence of Tinnitus

			Symptoms of Tinnitus				Total
			Yes Always	Yes Sometimes	Yes Occasionally	No Never	
Age of Respondent	20-29	Count	6	9	4	24	43
		% within Age of Respondent	14.0%	20.9%	9.3%	55.8%	100.0%
	30-39	Count	16	27	9	50	102
		% within Age of Respondent	15.7%	26.5%	8.8%	49.0%	100.0%
	40-49	Count	27	29	5	29	90
		% within Age of Respondent	30.0%	32.2%	5.6%	32.2%	100.0%
	50+	Count	20	3	1	16	40
		% within Age of Respondent	50.0%	7.5%	2.5%	40.0%	100.0%
Total		Count	69	68	19	119	275
		% within Age of Respondent	25.1%	24.7%	6.9%	43.3%	100.0%

Table 4: Respondent Years of Service in relation to incidence of Tinnitus

		Symptoms of Tinnitus				
		Yes Always	Yes Sometimes	Yes Occasionally	No Never	Total
1-10	Count	6	8	3	24	41
	% within Respondent Years of Service	14.6%	19.5%	7.3%	58.5%	100.0%
11-20	Count	20	28	11	46	105
	% within Respondent Years of Service	19.0%	26.7%	10.5%	43.8%	100.0%
21-30	Count	28	30	4	36	98
	% within Respondent Years of Service	28.6%	30.6%	4.1%	36.7%	100.0%
31-40	Count	15	2	1	13	31
	% within Respondent Years of Service	48.4%	6.5%	3.2%	41.9%	100.0%
Total	Count	69	68	19	119	275

Table 5: Age of Respondent in relation to incidence of High Blood Pressure

			High Blood Pressure		Total
			Yes	No	
Age of Respondent	20-29	Count	4	39	43
		% within Age of Respondent	9.3%	90.7%	100.0%
	30-39	Count	9	93	102
		% within Age of Respondent	8.8%	91.2%	100.0%
	40-49	Count	6	84	90
		% within Age of Respondent	6.7%	93.3%	100.0%
	50+	Count	4	36	40
		% within Age of Respondent	10.0%	90.0%	100.0%
Total		Count	23	252	275
		% within Age of Respondent	8.4%	91.6%	100.0%

Table 6: Age of Respondent in relation to Headache

			Headache		
			Yes	No	Total
Age of Respondent	20-29	Count	21	22	43
		Expected Count	19.9	23.1	43.0
		% within Age of Respondent	48.8%	51.2%	100.0%
	30-39	Count	45	57	102
		Expected Count	47.1	54.9	102.0
		% within Age of Respondent	44.1%	55.9%	100.0%
	40-49	Count	40	50	90
		Expected Count	41.6	48.4	90.0
		% within Age of Respondent	44.4%	55.6%	100.0%
	50+	Count	21	19	40
		Expected Count	18.5	21.5	40.0
		% within Age of Respondent	52.5%	47.5%	100.0%
Total		Count	127	148	275
		Expected Count	127.0	148.0	275.0

Table 7: Age of Respondent in relation to Annoyance

			Annoyance		Total
			Yes	No	
Age of Respondent	20-29	Count	9	34	43
		% within Age of Respondent	20.9%	79.1%	100.0%
	30-39	Count	27	75	102
		% within Age of Respondent	26.5%	73.5%	100.0%
	40-49	Count	27	63	90
		% within Age of Respondent	30.0%	70.0%	100.0%
	50+	Count	18	22	40
		% within Age of Respondent	45.0%	55.0%	100.0%
Total		Count	81	194	275
		% within Age of Respondent	29.5%	70.5%	100.0%

Table 8: Age of Respondent in relation to Other Diseases

			Other Diseases		Total
			Yes	No	
Age of Respondent	20-29	Count	2	41	43
		% within Age of Respondent	4.7%	95.3%	100.0%
	30-39	Count	3	99	102
		% within Age of Respondent	2.9%	97.1%	100.0%
	40-49	Count	6	84	90
		% within Age of Respondent	6.7%	93.3%	100.0%
	50+	Count	2	38	40
		% within Age of Respondent	5.0%	95.0%	100.0%
Total		Count	13	262	275
		% within Age of Respondent	4.7%	95.3%	100.0%