NOISE INDUCED HEARING LOSS IN A STEEL ROLLING MILL COMPANY IN NAIROBI, KENYA

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A study submitted in part fulfilment of the requirements for the degree of Master of Medicine in Ear, Nose and Throat- Head and Neck Surgery, at the University Of Nairobi.

DECLARATION

This dissertation is my original work and has not been presented for the award of a degree in any other university.

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DEDICATION

I dedicate this study to my loving parents, Mr. Avtar Singh Chauhan and Mrs. Gurcharan Kaur Chauhan for their love and patience.

Thank you mum and dad for believing in me

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ABBREVIATIONS

dB	Decibel.
dB (A)	Decibel with A weighted.
HL	Hearing Loss.
HPDs	Hearing Protective Devices.
Hz	Hertz.
IHCs	Inner Hair Cells.
KHz	Kilohertz.
NIHL	Noise Induced Hearing Loss.
NIOSH	National Institute for Occupational Safety and Health.
OHCs	Outer Hair Cells.
ONIHL	Occupational Noise Induced Hearing Loss.
OSHA	Occupational Safety and Health Act.
OAEs	Otoacoustic Emissions.
PTS	Permanent Threshold Shift.
SPL	Sound Pressure Level.
TTS	Temporary Threshold Shift.
TWA	Time Weighted Average.
WHO	World Health Organization.

ABSTRACT

Background: Occupational noise induced hearing loss (ONIHL) is a significant economic and health concern in the developing world but the prevalence among factory workers in Kenya is not well known. The iron and steel industry employees are exposed to excessive occupational noise as compared to other industries, hence vulnerable to permanent deafness. ONIHL is a preventable condition with effective occupational noise control strategies.

Objective: To determine the prevalence and risk of developing ONIHL in a group of production versus administrative non- production workers in relation to intensity and duration of noise exposure.

Study Site and Population: This study was conducted in a busy steel rolling mill based in the industrial area of Nairobi Kenya. 114 workers were randomly recruited and distributed equally between the two groups. All participants were male, 93.9% were below 50 years old, and 62.8% had at least secondary education.

Study Design and Methodology: This was a cross-sectional comparative study. Each participant had a structured questionnaire followed by tuning fork tests and a baseline audiogram. Noise mapping was done at various units

Data Analysis: Chi-squared tests for categorical variables and analysis of variance tests (ANOVA) for continuous variables were performed. Independent predictors of NIHL were determined using backward stepwise logistic regression. A p-value of less than 5% (p= <0.05) was considered statistically significant.

Results: A total of 39(34.2%) workers were found to have NIHL. From these, 17(81.0%) worked in the mill machine, 11(45.8%) were from the furnace, 5(41.7%) operated in the workshop and 6(10.5%) worked in the non-production administration unit.

The total duration of being employed as a factory worker was a statistically significant factor ($p<0.0305$) associated with NIHL. Factory workers who had served for 10-19 years were mainly from the administration group 19 (33.3%) as compared to 6(28.6%) in mill machine, 5(20.8%) in furnace, and 3(25.0%) in the workshop.

Exposure to high noise intensity was a significant factor ($p < 0.0001$) associated with NIHL. Mill machine workers had the highest risk of developing NIHL due to operating in the highest noise levels of 98.0 dB(A). The relative risk of developing NIHL for production unit workers was 33.1(95% CI 7.7-141.63).

In this study, using HPDs was not a significant factor ($p = 0.088$) in prevention of NIHL. Only 15(13.2%) workers had a pre-employment audiogram done in this factory

With the multivariate analysis, the factors associated with NIHL were duration of employment (OR 3.8, 95% CI: 1.17, 12.53; $p=0.001$), working in the production unit (OR 33.10 95% CI: 7.74, 141.63; $p<0.001$) and age (OR 3.03, 95% CI: 1.48, 6.17; $p=0.03$).

Conclusion: This study demonstrates that hearing loss is common among steel mill workers within this region. These findings qualify for implementation of an effective hearing conservation and rehabilitation policy that will protect and improve the quality of life of these mill workers.

1. INTRODUCTION

Noise is one of the most widespread pollutants in workstations. About six hundred million workers are exposed daily to unsafe occupational noise levels in the world (1). Excessive exposure to high intensity noise levels for a long duration of time results in irreversible hearing loss (2).

Globally, ONIHL accounts for 7 to 21% of permanent hearing loss with an estimated negative economic impact of 0.2-2% on the world's Gross Domestic Product (3).The World Health Organization (WHO) rates ONIHL among the top ten work related problems worldwide and top three causes of hearing impairment in Africa (4). In Kenya, the prevalence of NIHL ranges from 22%-32.5% (5, 6).

Steel is a useful raw material, which is vital to various upcoming industries within Kenya. The iron and steel industry is considered a 'heavy industry' (7) that forms a huge entity in Kenya and noise exposure for factory workers is an inseparable part of these industries. Several workers labour in these settings, forming a foundation to implement hearing conservation programs that will reduce the local burden within this country.

NIHL is preventable but it cannot be reversed. It persists even after the noise exposure is terminated as permanent damage has already occurred (2).

The purpose of this study was to identify the prevalence of NIHL and the associated risk factors among the workers of a Steel Rolling Mill in Nairobi, Kenya.

2. BACKGROUND

2.1. HISTORY OF NOISE INDUCED HEARING LOSS

Alberti et al (2) stated NIHL as a major occupational aural disorder after the discovery of gunpowder. In 1886, Thomas Barr (9) described the **'boilermaker's deafness'** related to shipbuilding. Haberman (10) demonstrated the histological features of NIHL in the organ of Corti within the inner ear in 1890. Afterwards, Fowler (11) described the characteristic noise-induced 4 kHz notch on an audiogram and in due course in 1939 and Bunch (12) explained the audiometric findings of NIHL. The technical advances of the Second World War fetched noisier machinery resulting to NIHL becoming more of a global problem.

2.2. DEFINITIONS OF SOUND AND NOISE

Sound is the propagation of pressure waves radiating from a vibrating source through an elastic medium (13). The waves are characterized by the amplitude of sound pressure changes (intensity), frequency (pitch), and the velocity of propagation (2). A simple type of sound wave is called a pure tone of one frequency. The source of such a sound is a sinusoidal pressure cycle defined in terms of a single frequency and pressure amplitude at a given time (13). The number of times such a cycle occurs in a given time is called frequency, which is measured in hertz (Hz = 1/sec).

Noise is characterized as any unwarranted disturbance within a useful frequency band (2). According to the time variation of the sound pressure level, noise is classified as continuous, intermittent, repetitive, discrete , and separated single impulses, with continuous being the most harmful(13). The effects of noise depend on intensity, spectrum, cumulative lifetime exposure, pattern, and individual susceptibility (2).

2.3. Definition of Noise Induced Hearing Loss

The WHO defines NIHL as bilateral sensorineural loss with a 0.5 KHz threshold of less than 50 dBHL (13). An individual with NIHL has had a noise exposure history of 100 dB (or 83 dB A) for a 50-year lifetime with at least a 15 dB difference between high and low frequency threshold averages (14).

2.4. Hearing level

Human ears can normally detect sounds within a frequency range of 20 Hz to 20 kHz, but are far more sensitive to sounds between 1 kHz and 4 kHz (14). Individuals can distinguish between tones with changes in frequencies between 0.3 % at 3 kHz and 3% at 100 Hz.

According to the International Standard Organization (15), normal ranges of audiometric frequencies are from 0.125 kHz to 8 kHz for both males and females between 18 to 70 years of age. The human speech range lies within the 250 Hz to 4000 Hz range.

2.5. Noise measurement and exposure

Noise exposure is the total sound energy reaching the inner ear (2). Total sound energy is a combination of sound intensity and duration. It is measured with a sound pressure meter in decibel (dB) units. A decibel is a tenth of a Bel that measures changes in air pressures. The logarithmic nature allows for representation of a large range of ratios and description of perceptual levels.

Sound intensity is also represented on a logarithmic scale of decibel SPL (Sound Pressure Level). On this scale, 0 dB SPL is a sound wave power of 10^{-16}watts/cm^2, the weakest sound detectable by the human ear. Normal speech is at about 60 dB SPL, while painful damage to the ear occurs at about 140 dB SPL (13Filter A (dB-A) is used to weight SPLs in accordance with the frequency response characteristics of the human auditory system for pure tones. It approximates the ear's response for a sound level below 55 dB with lower frequencies being filtered (16). The A-weighting is internationally used to assess occupational noise that will be employed in this study.

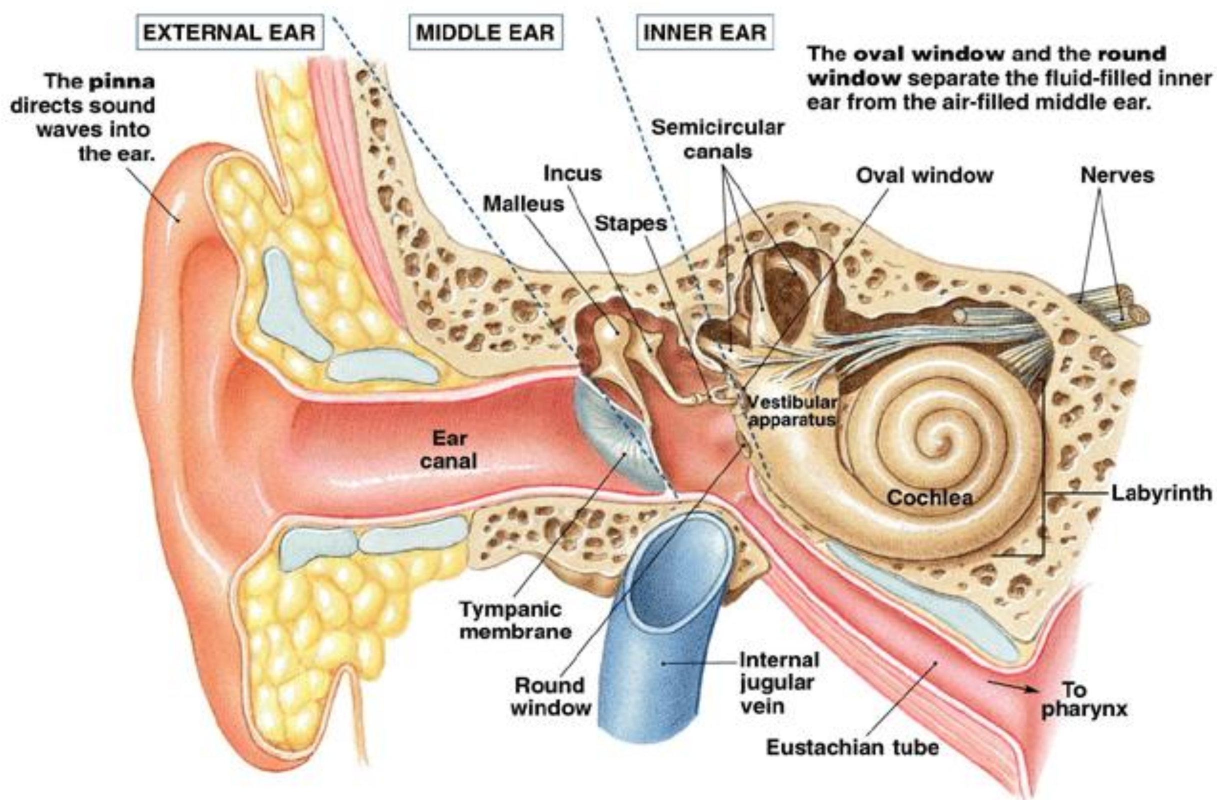
As per Chai et al, the usual noise levels in steel rolling mills vary from 81 to 100 dB (A) (17).

3. PATHOPHYSIOLOGY OF NOISE INDUCED HEARING LOSS

3.1. NORMAL PHYSIOLOGY

The ear is made up of the outer, middle, and inner ear, consisting of the auditory and vestibular pathway (Fig 1).Acoustic stimuli are transferred from the free field to the inner ear by the external and the middle ear.

Figure1. The major components of the right ear



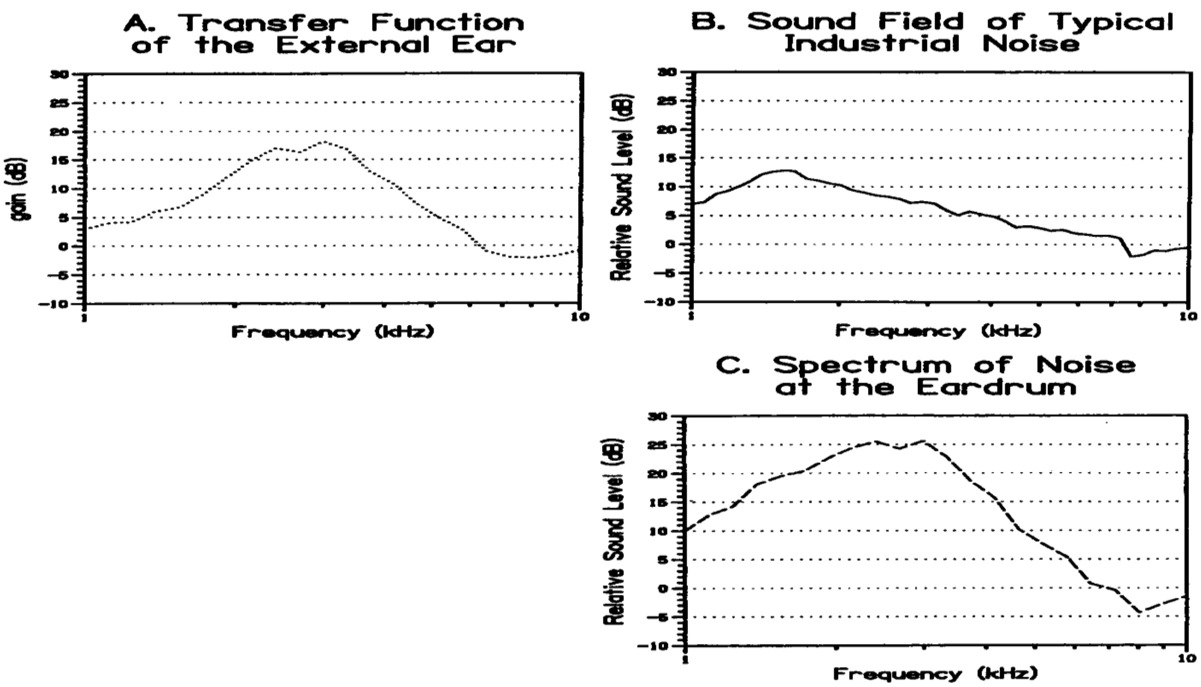
(Courtesy of: http://www.lyrichearing.com)

The external acoustic meatus and the middle ear transmit acoustic energy from air to the cochlea. The external acoustic meatus is approximately 25mm long with a resonant frequency of around 3,200 Hz, which helps determine the acoustic energy delivered to the cochlea(2).

The meatal resonance redistributes the sound pressure as it passes from the entrance of the external acoustic meatus to the tympanic membrane (2).

Amplification of sound pressure can be as great as 20 dB in the mid-frequency range depending on the direction and frequency of the sound source as illustrated in Figure 2A (8). Acoustic energy in the mid-frequency range is amplified when industrial noise travels through the external acoustic meatus, creating a band pass noise centred at 3200 Hz at the tympanic membrane (Figures 2B and 2C).

Figure 2:A. Resonance characteristics of a typical adult external auditory meatus. B. Spectrum of a typical industrial noise. C. Transformation of the industrial noise as measured at the tympanic membrane.



From: Hearing loss by Donald Henderson (8)

In steel mills, the external acoustic meatus creates a band pass noise, centred at 3 kHz since the noise is broadband (8). Hence, the 4 kHz notch is the result of the half-octave shift of the fundamental external meatus resonance (Fig. 2C).

There is a 40dB transmission loss when air-bone sound is transmitted to the fluid filled cochlea. This is compensated by the middle ear that serves as an impedance matching transformer, behaving like a low pass filter with an approximate cut-off of 1,200 Hz. The poor audiometric performance at high frequencies is explained by the attenuation at high frequencies (above 4 kHz) (8).

The noise threshold of at the cochlea ranges from 80-85dbA for the frequencies ranging from 500-4000Hz. The stapedial reflex prevents high noise levels from reaching the cochlea; hence protects against early hearing loss.

3.2. MECHANISMS OF DAMAGE

The inner ear consists of the cochlear, the semi-circular canals, and the vestibule. It contains the saccule and utricle, which are balance and equilibrium-related structures (2) as shown in Figure 3.When sound is conducted to the inner ear through the movement of the stapes footplate, it initiates a travelling wave that moves from the oval window to a point of maximum vibration along the basilar membrane. The relative displacements of the basilar membrane and of the tectorial membrane generate shearing motions of the outer hair cells (OHC), inner hair cells (IHC), and sterocilia (18).

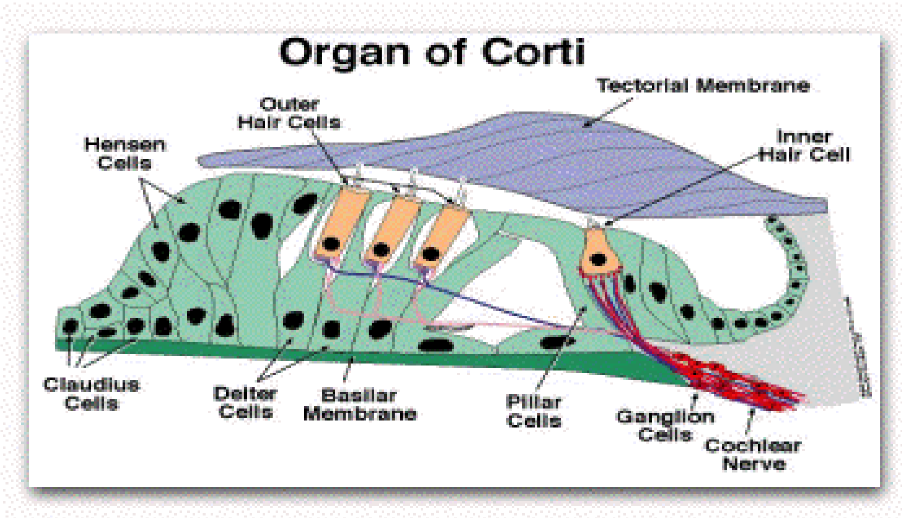


Figure 3: Schematic arrangement of the Organ of Corti.

(From: Research on the Organ of Corti of hearing in mammals. (Corti A 1851).

OHC mechanically assist in the vibration of the Organ of Corti that augments the sensitivity and the frequency tuning of the inner ear. Damage of OHCs is perpetually greater than IHCs following a traumatic noise exposure. They are more vulnerable to damage, since they experience a direct sharing force at their stereocilia, whereas the IHC stereocilia are stimulated by viscous drag. The OHCs have most of their long axis ‘unprotected’ from mechanical stress, whereas the IHCs are ‘supported’ on all surfaces with supporting cells. OHCs are also closer to the point of the maximal basilar membrane travelling wave displacement than are IHCs (2). OHCs are subject to damage from excessive shearing between the tectorial membrane and the cuticular plate via the ciliary connections.

If OHCs are damaged, a greater stimulation is required to initiate a neural impulse. This raises the threshold sensitivity of the IHCs, which is perceived as hearing loss. High levels of stimulation release an excess of neurotransmitter (glutamate) in IHCs leading to damage to associated nerve rootlets, which may be permanent (2). A person’s hearing can be reduced 40 to 50 dB with OHC damage. The ability to understand speech in a noisy background is also compromised due to degraded tuning of the basilar membrane. (19).

NIHL not only implicates the sensory cells, but also supporting cells, nerve fibres, and vascular supply. Secondary to very high levels of continuous sound, the hair cells in the Organ of Corti may be impaired directly by noise, or indirectly by vascular lesions (2). These vascular lesions may be the result of separations of Reissner’s membrane at its attachment to the lateral wall. This leads to a reduction in the number of capillaries and occlusion of vessels. The hair cells are anoxic and thus secondarily damaged (20). The extent of the effects of noise on cochlear blood flow is influenced by the length and intensity of the noise exposure.

Following severe exposures that lead to losses of IHCs, with a concomitant loss of inner pillar cells, there is a retrograde degeneration of VIII nerve fibres reflected in losses of spiral ganglion cells and morphologic changes in the ascending neural pathways (2).

High noise levels increase the level of metabolism, which increases the demand for ATP and consequently generation of superoxide. This free radical presence leads to further damage of proteins, mitochondria, DNA, and eventually leads to cell death (2).

The damage is worse after several days of a noise exposure insult. This is because of apoptotic cell death that continues for days after the exposure. This may be initiated by a Src–protein tyrosine kinase (PTK) signalling cascade that is activated in OHC following noise exposure (2).

High noise levels result in basal cell damage (21). This is attributed to the fact that high frequency stimuli cause maximal disturbance near the oval window involving greater travelling waves and acoustic load at the base. When the frequency is lowered, the peak of basilar membrane motion systematically shifts apically. There is also a possible basal locus for shock from abnormal impulse energy conducted to the cochlea (21).

3.3. Sound Intensity and Hearing

The type and amount of direct hair cell damage depends on sound intensity. When the ear is stimulated by sounds of 70 dB SPL or less, **adaptation** occurs. Above a certain minimum of frequency and intensity, the OHCs show signs of auditory fatigue through drooping of the stereo cilia and micro vascular changes (14).

Puel (22) described that, glutamate over secretion at the synapses between hair cells and the auditory nerve fibres leads to synaptic overload, swelling of synaptic terminals, and damage to both to the primary auditory nerve fibres and hair cells.

This relates to **Temporary Threshold Shift (TTS)**, in which the hearing threshold elevates during the first 8-12 hours of a noise exposure and recovers within 16 hours (23). TTS may last for several days or weeks if the noise exposure is sufficiently intense.

The level of a TTS is correlated to the causative noise's intensity, frequency, content, and pattern of exposure. The TTS produced by intermittent noise exposure is considerably less than the shift produced by continuous exposure to the same total amount of noise as stated by Glorig (24). This can be attributed to auditory fatigue.

Mills et al. (25) established that no TTS occurs until 74 dB at 4 kHz. Thereafter, a 4 kHz sound produces an asymptotic threshold shift of 1.7 dB for each decibel increase in sound level. Hence, the critical level is 74 dB at 4.0 kHz, 78 dB at 2.0 kHz, and 82 dB SPL at 1.0 and 0.5 kHz respectively.

If TTS occurs repeatedly, the recovery becomes less complete and a **Permanent Threshold Shift (PTS)** takes place**.** The threshold for TTS is between 78 and 85 dB (14). The 'injury threshold' is approximately 140 dB (14). Between these thresholds, are the 'discomfort thresholds,' namely discomfort (120 dB), tickle (125 dB), and pain (130 dB) (14). The risk between the two thresholds depends on the combined effects of noise level, duration, number of exposures, noise protection, and individual sensitivity.

PTS involves shortening of the cilial rootlets, disruption of the cochlear duct, loss of OHCs of the basilar turn, disruption of stria vascularis and neural degeneration of the first order neurons; hence irreversible. A non-functional scar tissue may involve only Deiter cells in the case of OHC losses, or the Claudius and inner sulcus cells in the case of near total loss of the Organ of Corti. PTS increases rapidly during the first 10 years of exposure, and then slightly increases between 20 and 50 years of exposure (26).

3.4 Impulse Noise

PTS can also be caused due to acoustic trauma with a sound stimuli ranging between 145-155 dB and often sustained for less than 0.2 seconds (13).

Acoustic trauma is primarily caused by impulse noise. Schmuzigert et al. (27) confirmed that impulse sounds produce loss at high frequencies with longer-lasting effects. The injurious potential is enhanced when impact noise is superimposed on continuous noise.

Acute acoustic trauma causes mechanical traumatic damage with micro-lacerations at the level of the basilar membrane and thus, the direct destruction of sensory cells, as well as biochemical damage, leading to edematous swelling of the hair cells. At high energies, both the tympanic membrane and ossicular injury can occur.

4. Combined Effects of Oto-traumatic Agents

Noise and aminoglycosides interrelate synergistically. They cause direct damage to the hair cells and disruption of the metabolism in the stria vascularis and spiral ligament, resulting to changes in cationic differences of the perilymph and endolymph.

Other ototoxic drugs such as cisplatin, quinine, and furosemide can cause oxidative stress resulting to generation of free radicals that in turn, damages the cells of the inner ear (28).

Noise exposure prior to receiving an ototoxic drug does not appear to affect the potential for ototoxicity. However, excessive noise pollution along with ototoxic drugs can cause a greater ototoxic effect (25). Ototoxic damage usually progresses from high to low frequencies.

Dobie (29) showed that the effects of presbycusis added linearly to the effects of occupational noise exposure. In sensory and mechanical types of presbycusis there is reduced auditory sensitivity at higher frequencies. By the age of 50-59, hearing loss at 16 kHz is greater than 60 dB (30). In this study, subjects over 55 years of age will be excluded in order to correct for age-related hearing loss.

A large number of other factors can affect hearing. These include middle ear disease, previous head injury, chemicals and bacterial infections, as well as over 40 genetic and metabolic syndromes (30).

5. Clinical Features

The first symptom of NIHL is trouble understanding speech in high levels of ambient background noise (2). As NIHL progresses, there is difficulty hearing consonants such as s,f,t,z (high pitched sounds). They are also unable to hear octaves such as high pitched sounds even in quiet conversational situations. Hence, sounds heard are distorted and voices may not be understood. As NIHL progresses, individuals have abnormal growth in loudness, known as recruitment. This results in a reduced dynamic range to a discomfort level.

More than 50% of individuals with NIHL report intermittent or continuous bilateral tonal tinnitus (31). Recent studies confirmed that when associated with NIHL, tinnitus is almost invariably of high pitch, with a tonal or narrow frequency-band timbre. Tinnitus appears early after an impulse noise and is usually temporary. With continuous long-term noise exposure, it appears after years, but remains permanent. The incidence and severity of tinnitus rises with increased hearing loss (2).

5.1 ESTABLISHMENT OF THE PRESENCE OF NIHL

Dobie listed the criteria for the diagnosis of Occupational NIHL (32):

- It is always a sensorineural hearing loss.
- It is almost always bilateral.
- High-frequency losses rarely exceed 75 dBA; low-frequency losses rarely exceed 40 dBA.
- In stable exposure conditions, losses at 3, 4, 6 KHz with recovery at 8 kHz reaching a maximum level in 10-15 years.
- Hearing loss does not progress after noise exposure is discontinued.
- As hearing loss progresses, the rate of hearing loss decreases.

6. DIAGNOSIS OF NIHL

A physical examination by otoscopy will evaluate the presence of cerumen impaction or evidence of middle ear disease. This will exclude other causes of hearing loss.

Tuning fork tests (Weber and Rinne) performed with a 512-Hz tuning fork will classify the loss into conductive or sensorineural. If there is sensorineural loss, the Rinne test will demonstrate air conduction better than bone conduction and the Weber test will lateralize away from that ear.

NIHL is identified with a calibrated audiometer in a sound attenuated room. The first sign is a ‘notching’ of the audiogram at 3000, 4000, or 6000 Hz, with recovery at 8000 Hertz (33). The greatest loss usually occurs at around 4 kHz which forms an acoustic notch (10) or a boilers notch (Figure 4).

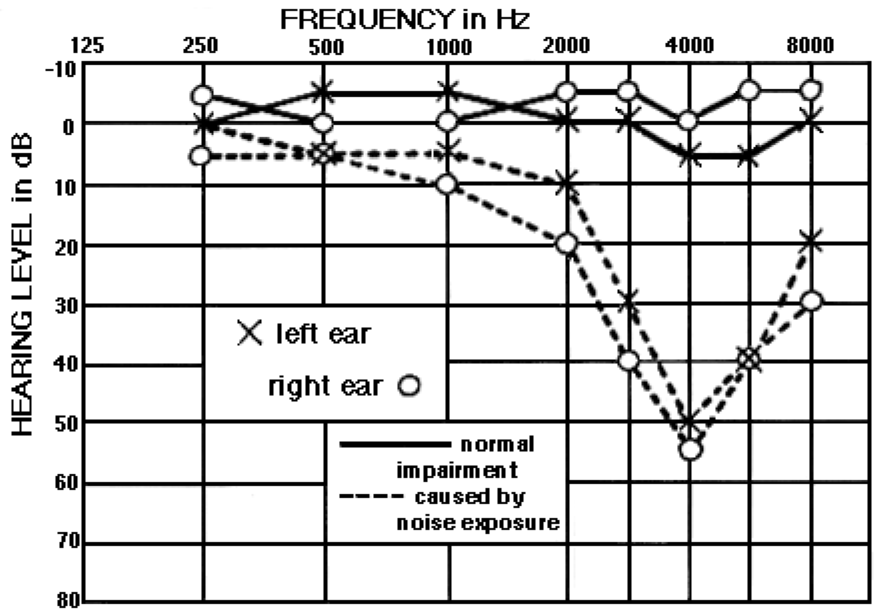


Figure 4: Audiogram with boiler's notch

(Courtesy of: Simon Fraser University, Canada)

The notching assists in distinguishing age related hearing loss, which shows a down-sloping pattern in the high frequencies without recovery at 8000 Hz. At the early stage of damage, the speech frequency area range (0.25 - 2 kHz) remains intact.

Symmetrical hearing loss is an important tool in diagnosing NIHL. Asymmetric losses (up to 10 dB) may be observed in noise-exposed subjects' .If a significant asymmetric loss is seen, one should relate this to other types of cochlear or retro cochlear lesions.

As hearing loss progresses with aging, the notch becomes less prominent, making audiometry to 8,000 Hz less diagnostic. The hair cell loss may be linked to poor sound discrimination, and an audiometric notch may be noticeable within six months to a year of starting a job with hazardous levels of sound. The major contribution of loss may occur quite early in the first 2 or 3 years, as late losses are contaminated with presbycusis. A significant number of NIHL cases don't have a notched audiogram (33).

The audiogram is subjective insensitive to subtle noise- induced cochlear changes. Otoacoustic emissions (OAEs) serve as a sensitive and quick tool for the diagnosis of NIHL. OAEs describe the responses the cochlea emits in the form of acoustic energy as a by-product of active processing by the OHCs. Attias et al. (34) showed increased sensitivity and specificity of OAE in the detection of early NIHL, whereby the distortion product OAEs reflect is a bilateral and almost symmetric loss in the high frequency tones. This study utilized the pure-tone audiometer due to lack of availability of this tool.

7. Types and Grading of Hearing loss

The types of hearing loss include conductive, sensorineural, and mixed hearing loss. The degree of hearing loss is described as the extent to which a person's threshold exceeds normal hearing (0-25 dB hearing level [HL]) and can significantly impact communication abilities and quality of life.

Grade of Impairment	Audiometric ISO value	Performance
0 (No impairment)	25 dBHL or less (better ear)	No or very slight hearing problems. Able to hear whispers.
1 (Slight impairment)	26-40 dBHL (better ear)	Able to hear and repeat words spoken in a normal voice at 1 meter.
2 (Moderate impairment)	41-60 dBHL (better ear)	Able to hear and repeat words using a raised voice at 1 meter.
3 (Severe impairment)	61-80 dBHL (better ear)	Able to hear some words when shouted into better ear.
4 (Profound impairment including deafness)	81 dBHL or greater (better ear)	Unable to hear and understand even a shouted voice.

Table 1: WHO classification of hearing loss(14).

The audiometric ISO values are averages of values at 500, 1000, 2000, 4000Hz.

8. The Damage Risk Criteria

The Occupational Safety and Health Act (OSHA) in the United States of America (35) delineate the maximum exposure time for unprotected ears as 85 Db (A) over a time-averaged, eight hour workday, five days a week for a minimum of five years.

The National Institute for Occupational Safety and Health (NIOSH) (36) predicts that one out of every four factory workers exposed to noise levels of 90dBA or more during lifetime will develop NIHL.

An average of 15% of the population are at risk of significant hearing loss after 10 years of 90 dBA exposure, 8 hours a day, 5 days a week. Seven per cent of the population is at risk for 10 years of 85dBA for a similar time-frame (36).

The Factories and Other Places of Work (37) law states that permissible levels in Kenyan production units should not exceed 90dBA for 8 hours of exposure. In non- production offices, the recommended noise levels are 50 Db (A) during the day and 45 Db (A) at night.

The damage risk criteria equates actual noise measurements at work over a period of years, in which several jobs have been held into a single risk figure for legal purposes (Table 2).

Sound Level dB(A)	Maximum Exposure Time(hours)
90	8
92	6
95	4
97	3
100	2
102	1.5
110	0.5
115	15 minutes

Table 2: Permissible Noise Exposure by OSHA (29 CFR 1910.95) (35).

Hearing protective devices (HPDs) should be provided to reduce the sound levels stated in Table 2 if administrative or engineering controls fail to reduce to safe sound levels.

9. PREVENTION OF NIHL

Besides avoiding excessive noise, wearing HPDs such as ear-plugs and earmuffs constitute an important preventive measure. The effectiveness of HPDs in prevention of NIHL is greatly dependent upon the correct use, wear, and compliance of the equipment. NIOSH recommends de-rating noise reduction by 75% for ear muffs, 50% for custom and foam earplugs (36). Further prevention methods include regular breaks, regularly serviced machinery and periodic audiometric testing.

10. LITERATURE REVIEW

A number of organizations together with the National Institutes of Health and the Centre for Disease Control and Prevention identify NIHL as a strategic target area for their efforts (38). In Africa, prevalence rates of 27.4-34% have been reported, indicating the magnitude of the problem (5, 39).

In 2004, Gitau et al. (5) conducted a study to determine prevalence of NIHL among textile industry workers in Eldoret, Kenya. He observed that 60% of workers in the weaving department had NIHL with an overall prevalence rate of 32.5%. Sound intensity level in the textile industry ranged from 33dB to 101dB with a mean daily exposure time of 7.67 hours. This was tallied with the local levels presented by Wambugu (40) in 1992. Noise levels in steel mills ranges from 81 to 100 dB (A), which may result in worse hearing loss as compared to the textile industry (17). In addition, 39.6% workers above 35 years of age in Gitau's study had a threshold shift towards hearing loss.

The Operation Eardrop- Kenya (6) implemented the Jua Kali Hearing Conservation Programme, where they surveyed 1200 Jua Kali workers and established 22% with hearing loss in Kisumu, which was analogous to a pilot study done in Nairobi that had 20% prevalence. This provides a strong bearing for this study since the Jua Kali workers (informal industry) frequently operate metal wares that may have similar noise levels. Furthermore, the noise survey showed 75% of the workers were exposed to noise levels exceeding 85 dBA on a daily basis.

However, the sheds were open, indicating interference from background noise that may impact on the accuracy of the actual noise levels. This study measured noise levels in a close setting. It was shown that majority of the workers had no knowledge of preventive measures against precarious noise levels, including HPDs.

A recent study by Anino et al. in 2010 (41) showed that occupational hearing loss in 246 aircraft crew members was much lower, unlike the textile and Jua Kali workers (informal industry) in Kenya. The prevalence of NIHL was 15.3%, with ground crew at 14.8% and air crew 16.1% at the Jomo Kenyatta International Airport in Nairobi. This can be attributed to compliances of HPDs. Respondents ranged from 22 to 62 years of age with a mean duration of exposure of 10.7 years. The ground crew had significantly worse mean hearing threshold levels at 3, 4, and 6 kHz, than the air crew with 50% working at the noisiest section of the airside ramp. Male workers were mainly affected with a male to female ratio of 4:3, whereas those aged 50 years and above had a 13.7 times higher relative risk than those aged 20 to 29 years. Exposure of more than 10 years was significant ($p < 0.01$) for hearing loss at 4 kHz. Hence, Anino recommended periodic audiometric assessment of workers targeting mainly the older vulnerable group. Conversely, background noise estimates were not recorded which would be necessary to determine subtle associations and trends.

Steel production room employees have been found to have a higher risk of NIHL compared to administrative employees despite working in the same factory as shown by Harmadji et al (42). He carried out a case control study with controls from the administration block at noise intensity levels of 60.4 dB and cases from the steel production room at 102 dB. A significant difference in the incidence of NIHL between the two groups was established, where 21 workers (84 %) of the case group developed NIHL, compared to one worker (4 %) of the control group in an Eastern Java steel company. There was also a difference in correlation between NIHL and working period ($p < 0.05$). This was also established by Chang et al. (43) with one hundred times more risk for NIHL among the in-field workers compared to the administration group in a liquefied petroleum gas cylinder infusion factory in Taipei City. Our study aimed to determine the difference in NIHL between production room and administrative staff in a steel mill.

The high risk of the exposed group is also confirmed in various case control studies by Ahmed et al. (44) and Shakhatreh et al. (45). Ahmed et al (44) in Saudi Arabia showed 38% of exposed subjects had NIHL, which was an 8-fold higher rate than that found for non-exposed subjects.

Likewise, Shakhatreh et al. (45) presented 30% of NIHL in the exposed group from a textile company in Jordan and 8% in non-exposed group from that community. The exposed group was four times more likely to develop hearing loss. This study will aim to describe the risk of hearing loss between the two different groups.

The duration of exposure affects the prevalence of hearing impairment as observed by Narlawar et al. (46) in workers of the Nagpur iron and steel industry in India. He saw a direct association, which was found to be statistically significant ($p < 0.001$). This has also been defined by Anino et al. (41), and Guerra et al. (47). Guerra's mean length of exposure to noise in the metallurgical company was 9.9 years. He showed that the length of exposure to occupational noise of 0 to 5 years had a prevalence of 8.3%, 6 to 10 years was 14.3%, and 20 years and over was 38.7%, respectively. He reported, however, that it may be over or underestimated due to a variety of interests, such as the obtaining of some legal assistance.

On the other hand, Ologe (48) in Nigeria carried out a cross-sectional comparative study in a steel rolling mill. His sample size was 159 from various sections in the mill. He showed that noise level ranged from 49-93 dBA. He noted that the average hearing threshold at 4 kHz for the groups increased with an increasing noise exposure level; so also was the pure-tone average.

A meta-analysis by Boger et al. (49) evaluated the noise spectrum influence on NIHL prevalence in workers as a cross-sectional historical cohort, carried out in steel mills, timber mills, and marble shops, with noise levels above 85dB. 53.8% of the workers from the metallurgical plants had an audiometric notch, followed by those from the timber mills, with 48.1%, and marble mills with 40.4%. In the metallurgical plants, the 8,000 Hz frequency band was the one that represents the highest noise level (85.4dB); hence, it is the most noxious to workers.

As to noise induced hearing losses (49.0%), they noticed that the frequency bearing the largest notches was at 6,000 Hz. Poor hearing levels of 23.4% in the left ear, compared to 13.8% in the right ear were also demonstrated.

Simon (50) described steel manufacturing as one of the industries with the highest levels of noise. Industrial noise pollution produces loud noise, which tends to last much longer. 52 to 60% of all industrial workers get exposed to noise level of 85 dB or more for 8 hours a day (50).

In 1992, Kilburn et al. (51) carried out a study on ironworkers, where he found that 25% of the study subjects had hearing loss at the 500 Hz frequency, while 60% had hearing loss at 8000 Hz, with the rest at 4000Hz. This study also linked hearing loss in ironworkers to increased balance dysfunction; an obvious concern for a worker population commonly performing work at elevated locations.

Minja et al. (52) carried out a study regarding NIHL among industrial workers in Dar-es-alaam, where 140 cases and 52 controls were recruited. 28 cases and 8 controls had NIHL. 81.1% of the cases and 85% of the employees knew that noise causes hearing loss, and all workers/employees from both study areas knew that noise induced hearing loss could be prevented by some form of ear protection. Masaka (39) established the knowledge of NIHL at a Zimbabwean mine to be 85%. Conversely, compliance with the use of HPDs was found to be low, with optimum usage only being achieved during the last 4 days of the 14-day observation period.

Table3: Summary of similar studies showing Occupational Noise Induced Hearing Loss

Author	NIHL Prevalence	Noise levels (dBA)	Special Remarks
Gitau et al. (2004) Eldoret,Kenya	32.5%	33-101	39.6% workers above 35 years of age had a threshold shift towards hearing loss.
OED (2009) Kenya	22% Kisumu 20% Nairobi	75% exposed to 85 dBA	Use of HPDs not explored.
Anino et al. (2010) Nairobi,Kenya	15.3% 14.8% with ground crew 16.1% with air crew	More than 90 dBA	Duration of more than a ten year exposure was significant ($p < 0.01$) for 4 KHz of hearing loss.
Ologe et al. (2004) Nigeria	28.2% mild –moderate HL in better ear 56.8% mild to moderate in worse ear.	49- 93	Pre-employment audiogram strongly recommended.
Masaka (2009) Zimbabwe	27.4%	81.2-125	Knowledge of HPDs = 85%
Shakhatreh et al. (1999) Jordan	30% exposed 8% non -exposed	46-95	Exposed group was 4 times more likely to develop HL when compared to the non-exposed group.
Chang et al. (2009) Taiwan	56.8%	55.4-98.3	None adopted noise-proof devices regularly at work. 100 times more risk for NIHL was found among these in-field workers compared to administration workers.
Guerra et al. (2005) Brazil	15.9%	83-102	Workers over 50 years of age had 11.45 times higher risk of getting NIHL.

12. JUSTIFICATION OF THE STUDY

As Kenya achieves its industrialization goals, many factories are likely to sprout up. This will subject the employees of these factories to the risk of NIHL due to exposure to excessive noise. ONIHL is therefore, likely to become a common health problem that will need to be addressed by the Kenyan health sector.

Although NIHL has been well recognized for a century within the steel rolling mills, it is weakly supported by epidemiological evidence in Kenya. This study will overcome the scarcity by providing an accurate quantification of the prevalence of NIHL. This data will assist in assessing the risk and burden of disease and enhance various Health Conservation and Rehabilitation programs to improve the quality of life of factory workers in Kenya.

13. RESEARCH QUESTION

What is the prevalence of noise induced hearing loss among workers in a steel rolling mill in Nairobi, Kenya and what are the likely associated risk factors?

14. AIMS AND OBJECTIVES

14.1BROAD OBJECTIVE

To identify the prevalence and risk factors associated with NIHL in a steel mill.

14.2SPECIFIC OBJECTIVES

1. To establish the prevalence of NIHL among steel mill workers.
2. To compare the prevalence of NIHL between production unit and non-production unit workers.
3. To determine the possible risk factors for NIHL in Steel mill workers.

15. MATERIALS AND METHODS

15.1. STUDY DESIGN

A comparative cross-sectional study based in a steel rolling mill company

15.2. SETTING

A major steel rolling mill factory in Nairobi, Kenya, that manufactures twisted bars for construction.

15.3. STUDY POPULATION

All steel rolling mill workers with a minimum of five years of continuous service, formed the study population.

15.4. INCLUSION CRITERIA

- Mill workers who had been working at the factory for a minimum of 5 continuous years.
- Mill workers who signed an informed consent.

15.5. EXCLUSION CRITERIA

- Those who worked for less than 5 years in the current mill.
- Workers 55 years of age and older whose hearing loss may be complicated by presbycusis.
- Workers with significant concurrent noise exposure.
- Workers who had been using ototoxic medication.
- Workers with conductive hearing loss.
- Workers with a history of previous middle ear infection.
- Workers with history of previous ear surgery or head injury.
- Workers with systemic disease affecting their hearing.

15.6 Sample size calculation

The determination of sample size in studies comparing two proportions was calculated using the formula (53)

$$n_1' = \frac{\left\{z_{\alpha/2}\sqrt{(r+1)\overline{p}\,\overline{q}} + z_\beta\sqrt{rp_1q_1 + p_2q_2}\right\}^2}{rd^2}$$

Where:

Probability of "Hearing Loss" in "Factory Workers" group p1		30%
Probability of "Hearing Loss" in "Office Workers" group p2		0.8%
p1 - p2 =d		0.22
Odds Ratio OR		4.93
Proportion of participants expected in production unit workers		50%
Proportion of participants expected in non-production workers		50%
Ratio of (production workers: non-production workers) sizes r		1.00
P corrected	p-bar	0.190
Power	1-β	80%
	z-β	0.84
Confidence level	1-α	95%
	z-α	1.96
Number of subjects required for ‘production workers’ (n1)		49
Number of subjects required for ‘non-production workers’ (n2)		49
Continuity correction for n1' n1		57
Continuity correction for n2' n2		57
Sample Size		114

Figures were rearranged to achieve 80% power of the study, with prior reference from Gitau et al. (5).

15.7 METHODOLOGY

15.7.1. RECRUITMENT OF SUBJECTS

Participants were selected from their appointment list in both the production and non-production sections, using a simple sequential sampling. A brief history was taken to screen for workers who satisfied the inclusion criteria. 57 participants from each section were then recruited, approached, and briefed about the study and enrolled upon consent (Appendix 1).

15.7.2. NOISE MAPPING:

Noise was measured with the Cirrus: 263 Type1 Noise Meter with 1:1 Octave Filter on a dBA scale that was calibrated.

For the administration unit, readings were taken at the entrance, in the middle, and at the end of the administration unit for an average of eight hours between eight am and five pm for five days. For the production unit, noise was measured in the furnace, the mill machine, and the different sectors, respectively. Three readings were taken at the entrance, middle, and the end of each of these units. These were recorded when sound levels were noted to be steady for 15 seconds. Electroacoustic calibration of the noise meter was performed each time before data collection.

15.7.3. DATA COLLECTION

A face-to-face interview with each of the workers was conducted. A standardized, anonymous questionnaire (Appendix 3) was used to obtain their socio-demographic data (age, gender, education), employment (in this factory and as an overall factory worker), and medical history (tinnitus and vertigo) including use of any HPDs.

15.7.4. CLINICAL EXAMINATION,

A physical exam was done with an emphasis on ear examination. Preliminary otoscopic exam with a Welch Allyn MOD 95001otoscope was done to rule out any aural condition. Any foreign bodies or wax was removed before conducting audiological tests. Any pathology noted was referred to Kenyatta National Hospital clinic 34

Weber and Rhinnes tuning fork tests were performed with an ADC Aluminium Alloy Tuning Fork, 512 Hz Model: 500512 to identify whether the loss was conductive or sensorineural.

15.7V. AUDIOMETRIC MEASUREMENTS

All participants had pure-tone audiometric tests with an interacoustic AS216 diagnostic audiometer Model: MD04503 complying with ISO 8253.Daily calibration was conducted before subjects were tested, by setting the audiometer to scale 0. Both air and bone conduction audiometry was done to determine the type of hearing loss. Pure-tone averages were calculated for frequencies 0.5-6.0 kHz, and hearing loss was graded according to the WHO (14).

The audiometric measurements were conducted in a quiet office (30dB (A) in the company by an audiologist. The measurements were done before the workers entered the work area. Thus the workers had been away from noise for more than 16 hours. This helped us to show the distinction between PTS and TTS.

The participant was relaxed and the procedure was explained. Ear phones were placed and each ear was being tested separately.

After placing the ear phones, the participant was then asked to press the button once he/she heard a tone. The process was started with the better ear based on the subject's report. If hearing was reported to be the same in both ears; we began with the right ear. A sound stimulus was presented to the ear of the listener at an intensity of 60dB at frequency of 1000Hz. If it was not heard, it was increased in steps of 20 dB until the response was obtained. Once the subject responded, a threshold search began by decreasing intensity by 10 dB if he/she heard the tone, or increased by 5 dB if the tone was not heard. A threshold was considered to be the lowest level at which the subject perceived the tone approximately 50% of the time.

This process was repeated for 2000, 3000, 4000, 6000, 8000, 500 and 250 Hz. The same was done for the other ear. Bone conduction was measured by a vibrator, placed on the mastoid.

Masking was indicated where the difference between the left and right air conduction thresholds were 40 dB or more. These findings were then plotted on a standard form for both ears (Appendix 4).

16. Quality control

The questionnaire was pretested on 10 conveniently sampled workers (5 each from their respective units). Special attention was paid to the sensitivity and acceptability of the questions, as well as ambiguity. This ensured that questions were set in a logical manner, were appropriate and obtained useful answers. All 10 workers included in the pilot study were excluded from the study to avoid bias.

Daily calibration was conducted before subjects were tested to avoid errors. The principal investigator carried out the questionnaire, took noise measurements, and physical examination. Audiometric tests were done by a qualified audiologist in both groups to eliminate observer bias.

17. Data management and Statistical analysis

Data was entered into a database and stored in a password protected database in Microsoft access version 2010. The principal investigator checked for correctness once the data entry was complete. Data was then exported to SPSS version 20 for analysis with the help of a statistician.

The prevalence of NIHL was estimated by computing the number of persons with NIHL among people who had been exposed to industrial noise. Continuous variables were summarized using measures of central tendency and dispersion, whereas categorical variables were summarized using frequencies and percentages. To compare differences between respondents working in the production unit with those working in the non-production units, chi-squared tests for categorical variables and analysis of variance tests (ANOVA) for continuous variables were performed. Independent predictors of NIHL were determined using a backward stepwise logistic regression.

For this study, a p-value of less than 5% (p-value of < 0.05) was considered statistically significant.

18. Data presentation

Results are presented in the form of charts, tables, text, and graphs.

9. ETHICAL CONSIDERATION

The study was approved by the Kenyatta National Hospital /University Of Nairobi Ethics and Research Committee ethical and research committee (Approval number P405/09/2011). Permission to perform the study was obtained from the owners of the steel mill.

Participants were given information about the study before taking consent and being inducted into the study. They had the full authority to decline and participation. (Appendix1- tool for taking consent)

Participants did not incur any extra cost for participating in the study. Costs incurred were borne by the principal investigator.

Patient information was held confidential to ensure privacy.

Participants reserved the right to withdraw from the study at any time without any penalty.

The subjects were not given any monetary inducement to participate in the study.

The results were to be published in periodical, electronic and print media where applicable. Both the mill owner and factory workers were to be offered benefits from the study.

20. IMPLEMENTATION TIMETABLE

Proposal Writing	December 2010-September 2011
Ethics Review Committee	July- August 2014
Data Collection	September –October 2014
Data Analysis	November-December 2014
Presentation of Results	May 2015

21. BUDGET

ENTITY	COST(Shillings)
Stationary	30,000
Otoscope	5,000
Tuning fork	2,500
Syringe set	4,300
Noise meter1500x15[Hire]	15,000
PTA(30X3000)[Hire]	90,000
Transport	18,000
Biostatistician	30,000
Contingencies	15,000
TOTAL	209,800

22. RESULTS

The pie chart below shows the distribution of workers in the various sections of the factory.

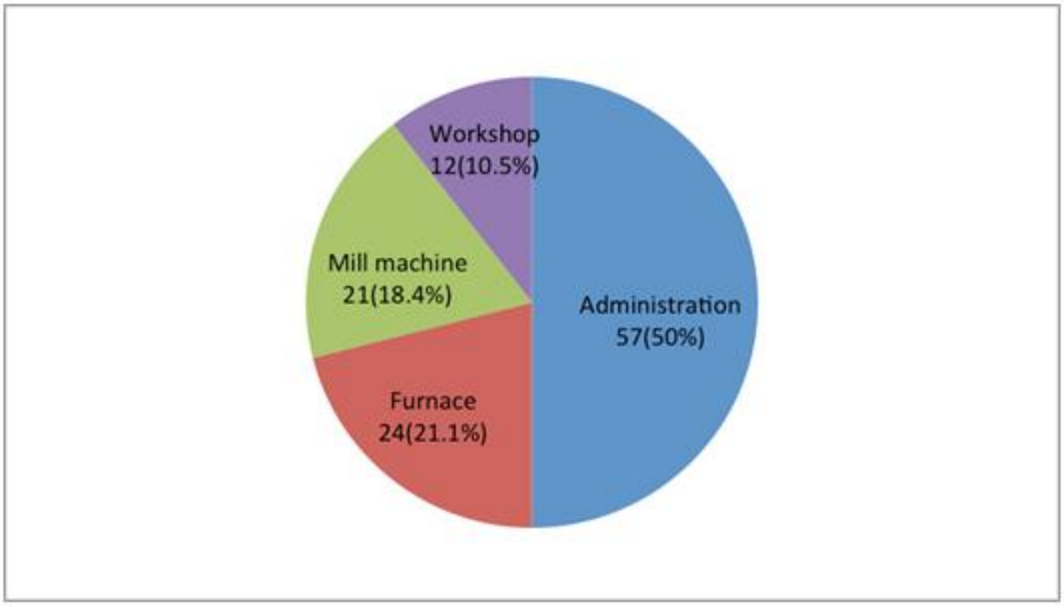


Figure 5: Pie chart showing distribution of selected workers

All participants were male aged between 24 to 54 years of age with a mean age of 35 years. Subjects more than 55 years were excluded to correct for presbycusis.60 (52.6%) workers fell into the 30-39 age brackets with 35 (61.4%) from the non- production unit and 25(43.9%) from the production unit. 7(6.1%) individuals were above 50 years, with 4(7.0%) from the administration unit as shown in Figure 6.

Of all the workers, 58(51.3%) had a secondary education level with 35 (30.7%) from the non-production unit and 23(20.1%) from the production unit.13 (11.4%) workers had a tertiary education from the non- production unit. This is shown in Figure 7 below:

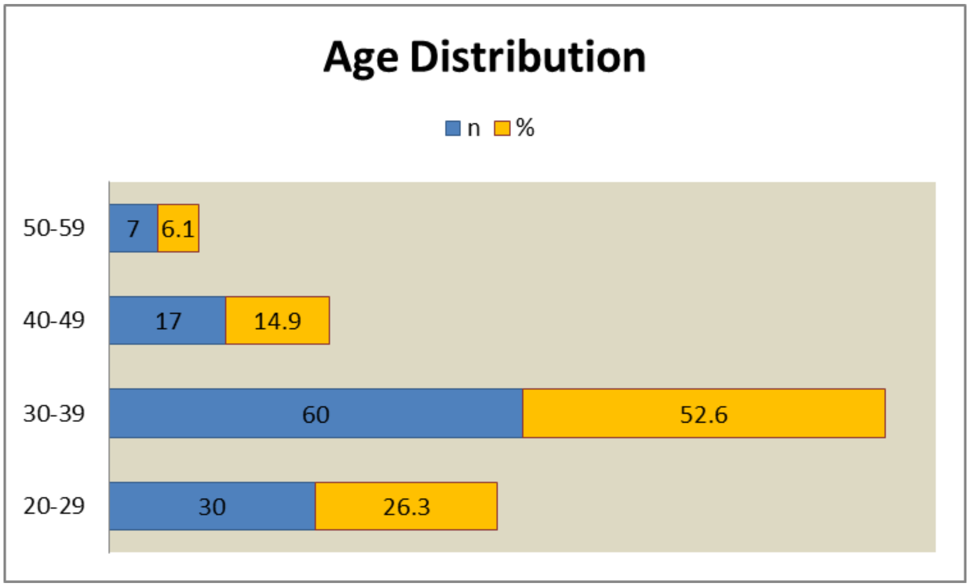


Figure 6: Bar Chart showing distribution of age among mill workers

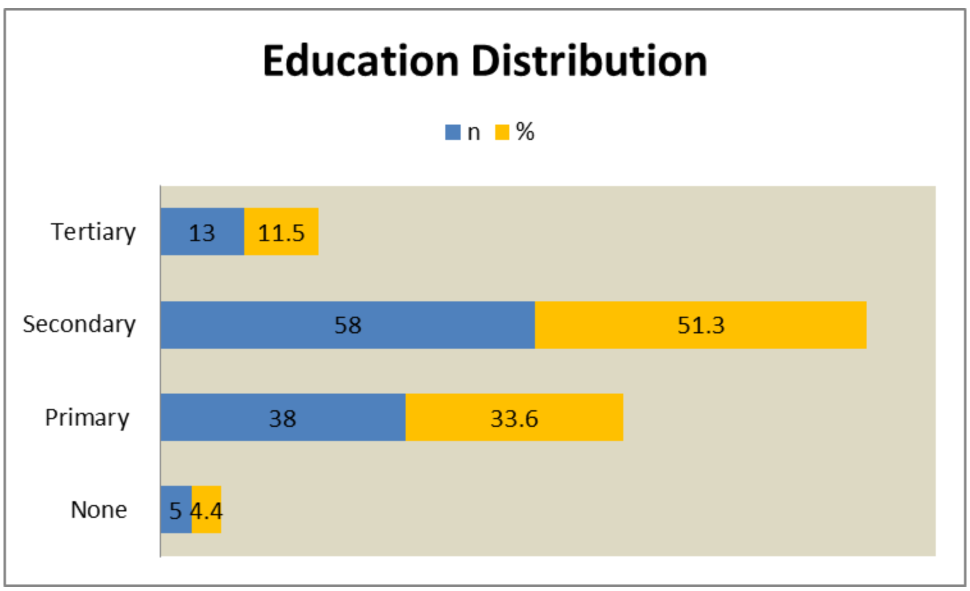


Figure 7: Bar Chart showing education level among mill workers

The difference in age and education between the two groups is statistically significant (p <0.05) as shown in tables 4 and 5 below:

Table 4,5: Bivariate analysis of age and education between two groups

VARIANT		Unit					
		Non-production		Production			
		n	%	n	%	Chi square	P value
Age group	20-29 years	11	19.3%	19	33.3%	4.472	0.215
	30-39 years	35	61.4%	25	43.9%		
	40-49 years	7	12.3%	10	17.5%		
	50-59 years	4	7.0%	3	5.3%		
Education	None	0	0.0%	4	7.1%	30.003	<0.0001
	Primary	9	15.8%	29	51.8%		
	Secondary	35	61.4%	23	41.1%		
	Tertiary	13	22.8%	0	0.0%		

VARIANT		NIHL					
		No		Yes			
		n	%	n	%	Chi square	P value
Age group	20-29 years	24	80.0%	6	20.0%	8.966	0.030
	30-39 years	40	67.8%	19	32.2%		
	40-49 years	7	41.2%	10	58.8%		
	50-59 years	3	42.9%	4	57.1%		
Education	None	3	75.0%	1	25.0%	12.045	0.007
	Primary	18	48.6%	19	51.4%		
	Secondary	40	69.0%	18	31.0%		
	Tertiary	13	100.0%	0	0.0%		

Noise Intensity

Noise levels were highest in the mill machine, 98.0 dB (A) followed by workshop 96.0 dB (A), furnace 93.1dB (A), and lastly administration 60.0 dB (A). This is shown in the stacked pyramid chart below

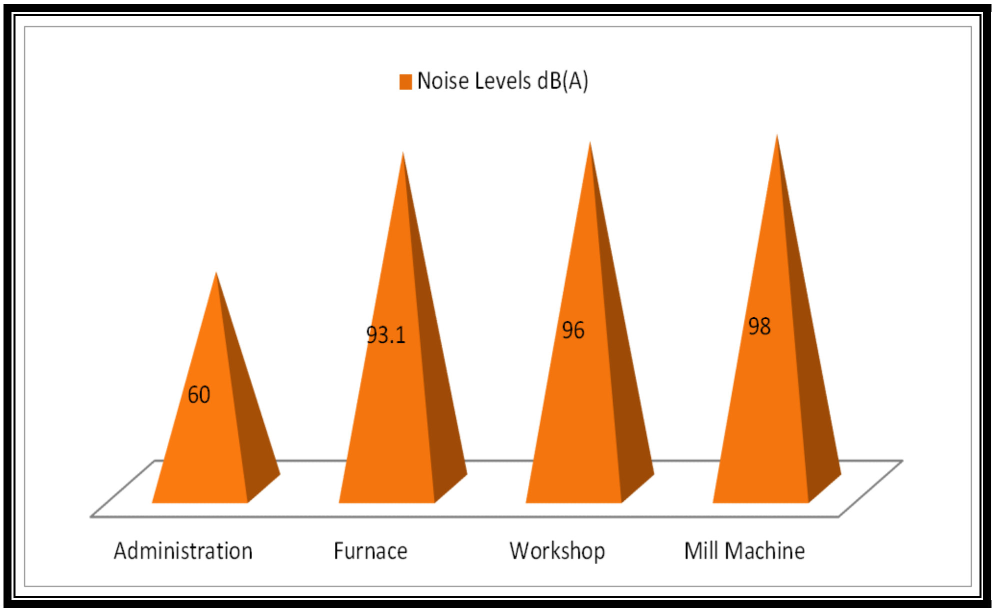


Figure 8: Pyramid chart showing noise levels in various units

At least 43(37.7%) workers reported high noise levels at their worksite with 11 (9.6%) stating the noise to be very high. 73(64%) of all workers described the noise to be continuous at their work units, from which 45(39.4%) belonged to the production unit. A number of 32(28%) defined it as intermittent, irregular in nature. This is shown in table 6 below:

Noise Description		Unit					
		Non-production		Production			
		n	%	n	%	Chi square	P value
How would you describe the type of noise that you are exposed to in your work environment	Continuous (Nonstop)	28	49.1%	45	78.9%	11.237	0.004
	Intermittent (irregular or broken)	22	38.6%	10	17.5%		
	Impact (Banging)	7	12.3%	2	3.5%		
How would you describe the noise levels at your work site	Negligible	23	40.4%	2	3.5%	40.763	<0.0001
	Low	23	40.4%	12	21.1%		
	High	10	17.5%	33	57.9%		
	Very high	1	1.8%	10	17.5%		

Table 6: Bivariate analysis of age and education between two groups

Duration of Exposure

Duration of working years was presented as the duration in the current mill and the total time as a factory worker respectively.

All employees worked for 6 days a week, with various exposure hours and breaks. The administration unit workers were exposed to a total of 42 hours a week. This was similar to the workshop workers, however, they were subjected to higher noise levels of 96 dB (A).

The furnace staff had the most exposed hours of 66 hours per week as compared to mill machine workers who did 54 hours per week. All workers were given an hour of lunch break except mill machine workers who had 2 hours as shown in Table 7 below. From this table, it is clear that the furnace and mill machine production workers were exposed for longer hours as compared to the workshop and administration units respectively.

Table 7: Number of hours exposed per week in each unit

Task	Noise Level dB(A)	Hours worked/day	Break hours/day	Hours worked/week	Break hours/week	Total hours exposed/week
Administration	60.0	8	1	48	6	42
Furnace	93.1	12	1	72	6	66
Mill machine	98.0	11	2	66	12	54
Workshop	96.0	8	1	48	6	42

The odds of getting NIHL among workers in production is 33 times (95%C.I. 7.4 – 141.6) than the odds of getting NIHL among works in the administration department.

The relative risk of having NIHL in various production units compared to non- production unit is shown below in Table 8.

Production Unit	Relative Risk
Mill Machine	7.7
Furnace	4.36
Workshop	3.97

Table 8: Relative Risk of having NIHL in various production units as compared to non-production unit.

In the current mill, workers who had served for 0-9 years were mainly from the non-production unit as 41(71.9%). From the production unit, 20(83.3%) furnace workers, 19(90.5%) mill machine workers and 8(66.7%) workshop workers had worked for 0-9 years as seen in the Table 9 below.

The total time worked in a factory setting for the 10-19 year range had 19 (33.3%) administration workers, 6 (28.6%) mill machine workers, 5 (20.8%) furnace workers and 3 (25.0%) workshop workers. This showed that the administration unit workers were the longest serving factory employees in both settings as compared to the production unit workers.

The working duration in different groups was significant (p = 0.003).

Task	Duration of years worked	Total time worked in a Factory Setting		Total time worked in current Factory	
		Number of workers	%	Number of workers	%
Administration	0-9 years	33	57.9%	41	71.9%
	10-19 years	19	33.3%	14	24.6%
	20-29 years	3	5.3%	1	1.8%
	30 years and above	2	3.5%	1	1.8%
Furnace	0-9 years	17	70.8%	20	83.3%
	10-19 years	5	20.8%	4	16.7%
	20-29 years	2	8.3%	0	0.0%
	30 years and above	0	0.0%	0	0.0%
Mill machine	0-9 years	14	66.7%	19	90.5%
	10-19 years	6	28.6%	2	9.5%
	20-29 years	0	0.0%	0	0.0%
	30 years and above	1	4.8%	0	0.0%
Workshop	0-9 years	8	66.7%	8	66.7%
	10-19 years	3	25.0%	3	25.0%
	20-29 years	1	8.3%	1	8.3%
	30 years and above	0	0.0%	0	0.0%

Table 9: Duration of noise exposure in various tasks

The multivariate analysis showed that working previously in an excessive noisy environment was significant, with an odds ratio of 3.8, and a 95% CI of 1.17-12.5 as shown in Table 10 below.

	Coefficient	Standard Error of coefficient	P value	Odds Ratio	95% C.I. for OR	
					Lower	Upper
Previous work in excessive noise environment	1.344	0.604	0.026	3.835	1.173	12.539

Table 10: Previous noise exposure and hearing loss.

Hearing Loss

As per the WHO classification, 48(42.1%) mill workers had a sensorineural hearing loss, from which 10(8.8%) had a mild impairment, 29(25.4%) had a moderate loss and 9(7.9%) had severe hearing loss as shown in the pie chart below.

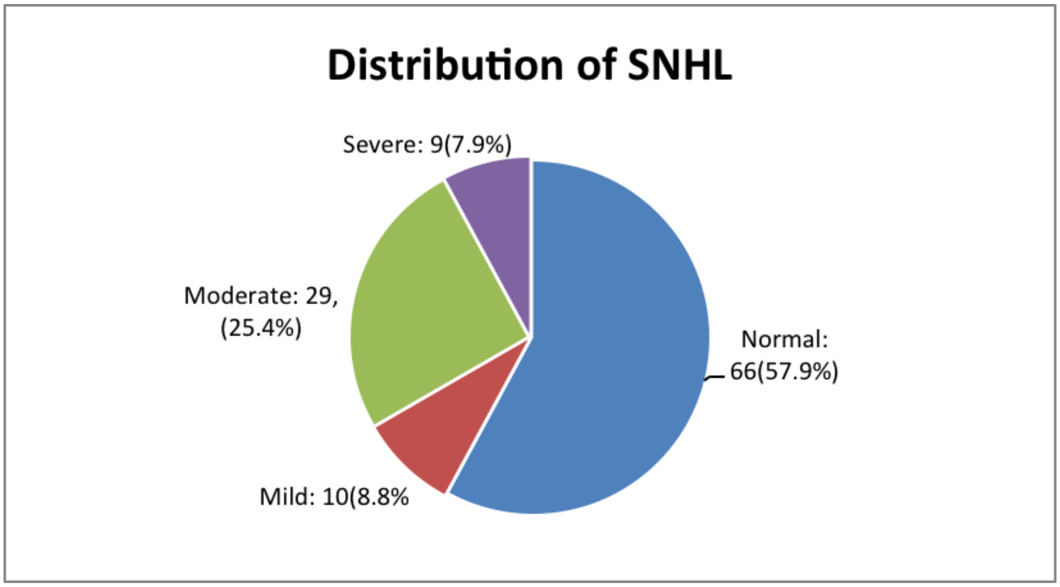


Figure 9: Pie chart showing distribution of hearing loss among mill workers

Of all the workers, 39 (34.2%) were found to have developed NIHL as per the Dobie criteria (25). These were 33(84.69%) from the production unit and 6 (10.5%) were from the administration unit. 17(81.0%) of the production workers with NIHL worked in the mill machine, 11(45.8%) were from the furnace, 5(41.7%) operated in the workshop. This is shown in Figure 10 below.

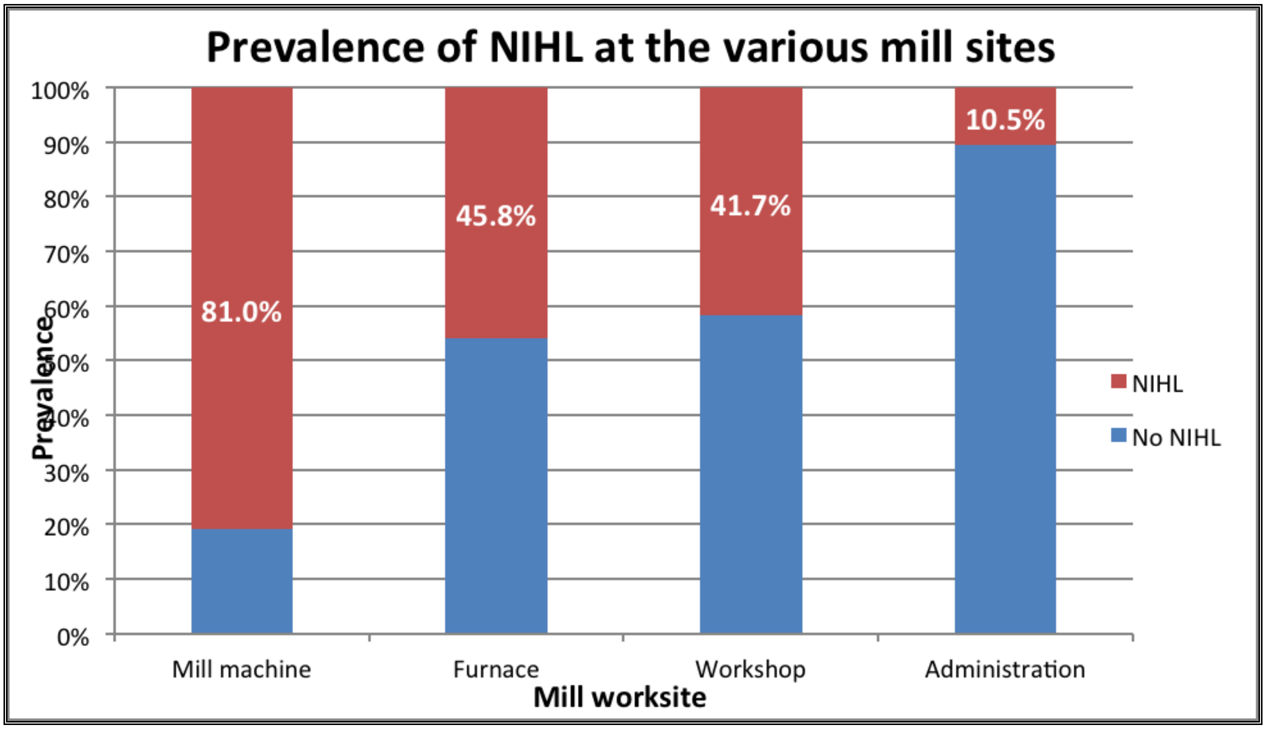


Figure 10: Bar chart presenting Prevalence of NIHL among steel mill workers

There was a significant difference between the two groups in the incidence of NIHL with $p < 0.0001$.

The boilers notch was present at 3 and 4 KHz with the 4 KHz notch highest in 17 (81.0%) of mill machine workers as shown in Table 11.The 3 KHz notch was noted in four furnace workers who had been factory workers for a minimum of 15 years, as well as one administration worker. This particular mill supervisor had been a factory worker for 27 years, having worked for 6 years in the current mill.

Table 11: Distribution of Notch at 3 and 4 KHz

Task	NOTCH (KHz)			
	3		4	
	n	%	n	%
Administration	1	1.80%	5	8.80%
Furnace	4	16.70%	7	29.20%
Mill machine	0	0.00%	17	81.00%
Workshop	0	0.00%	5	41.70%
Total	5	4.40%	34	29.80%

It was noted that 19(16.7%) of the workers had tinnitus. From these, 7(29.2%) were furnace workers and 6(10.5%) were administration workers as shown in the Figure 11 below.

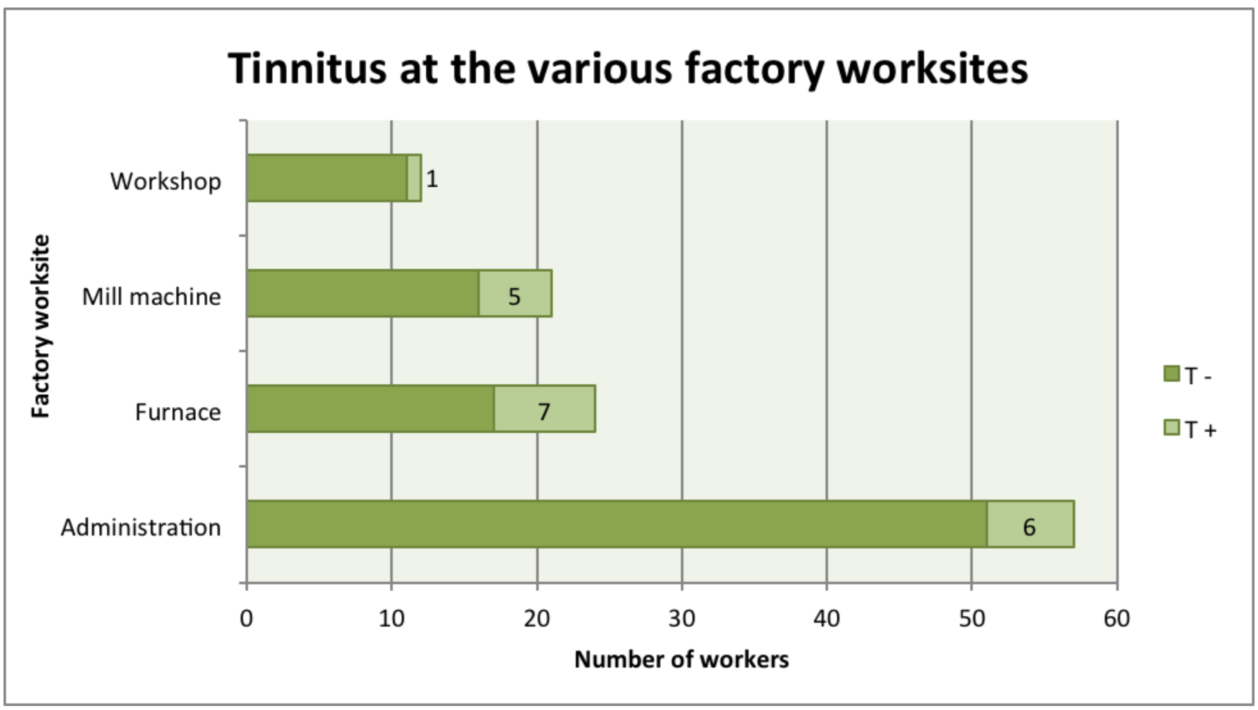


Figure 11: Chart showing number of workers who presented with Tinnitus

Use of Protection Devices

A total of 28 individuals (24.6%) reported daily use of HPDs at their units as shown in Table 12.

Task	Use protective equipment for ears	
	n	%
Administration	5	8.80%
Furnace	9	37.50%
Mill machine	10	47.60%
Workshop	4	33.30%
Total	28	24.60%

Table 12: Table showing use of HPDs in various units

The HPDs used included formable earplugs at 58.3%, earmuffs at 33.3%, and pre-moulded earplugs at 8.3% as shown in the Table 13 below.

The rest of the 34 production workers who did not use HPDs gave various reasons including issues such as no education (4 workshop workers) and discomfort (7 furnace workers).

Table 13: Use of hearing protective devices and various types.

Task		Pre-molded earplugs		Formable earplugs		Earmuffs	
	n	%	n	%	n	%	n
Administration	0	0.0%	1	50.0%	1	50.0%	1
Furnace	0	0.0%	3	37.5%	5	62.5%	3
Mill machine	2	20.0%	2	20.0%	6	60.0%	2
Workshop	0	0.0%	2	50.0%	2	50.0%	2
Total	2	8.3%	8	33.3%	14	58.3%	8

A total of 71.95% of the workers reported that they had not been given HPDs as shown in Table 14

TASK	REASON									
	Not Educated on use		Feels hot		not aware of HPDs		Worried will not hear danger signs		Not provided	
	n	%	n	%	n	%	n	%	n	%
Administration	2	3.5%	0	0.0%	1	1.8%	3	5.3%	51	89.5%
Furnace	1	4.2%	1	4.2%	0	0.0%	7	29.2%	15	62.5%
Mill machine	5	23.8%	1	4.8%	0	0.0%	5	23.8%	9	42.9%
Workshop	4	33.3%	0	0.0%	0	0.0%	1	8.3%	7	58.3%
Total	12	10.5%	2	1.8%	1	0.9%	16	14.0%	82	71.9%

Table 14: Reasons for not using HPDs

Only 15 individuals (13.3%) had a pre-employment audiogram. From these, 10 (17.9%) belonged to the production unit and only 5 (8.8%) were from the non-production unit. None of the workers presented these audiograms to the examiner to assess hearing loss.

From the multivariate linear analysis, the associated factors of NIHL were age (Adjusted OR 3.03, 95% CI: 1.48, 6.18; p=0.002), previous work in an excessive noise environment (Adjusted OR 3.8, 95% CI: 1.17, 12.53; p=0.026), and working in the production unit (Adjusted OR 33.10 95% CI: 7.74, 141.63; p=0.0).

	Coefficient	Standard Error of coefficient	P value	Adjusted OR	95% C.I. for OR	
					Lower	Upper
Age	1.109	0.363	0.002	3.033	1.489	6.178
History of ear problems	1.912	0.662	0.004	6.766	1.849	24.756
Previous work in excessive noise environment	1.344	0.604	0.026	3.835	1.173	12.539
Production unit	3.500	0.742	.000	33.109	7.740	141.634

Table 15: A Multivariate Analysis showing significant factors associated with NIHL and their Adjusted Odds ratios.

23. DISCUSSION

NIHL is associated with exposure to excessive noise (39, 44, 45, and 48). In Kenya, limited data has been presented from the iron and steel industries, which has been reported to be one of the factories with high noise levels (50). Our study selected one of the busiest steel rolling mills at the heart of industrial area in Nairobi, Kenya. It comprised of 300 workers with 60 in the non-production unit (administration unit) and 240 in the production unit. The mill was operational from 7am to 7pm, 6 days a week with four main operational units namely the administration block, workshop, furnace and the mill machine.

This study confirmed that excessive noise is a crucial occupational health hazard in the selected steel rolling mill. The major risk factors for ONIHL were the duration of employment and the intensity of noise exposure. This relationship is similar to that observed in previous studies in Zimbabwe, Nigeria, Taiwan and Jordan (39, 48, 43 and 45).

The steel industry has been known to be one of the industries with very high sound intensity levels (50).Individuals exposed to excessive high intensity sound levels will develop a hearing threshold shift, which may be either be TTS or PTS (23, 29) subject to duration of exposure. In this steel mill the sound levels ranged from 60 dB A to 98 dB A. The highest sound exposure levels in the mill machine sector had already exceeded the permissible noise levels as stated by OSHA (35) and the Kenyan 2005 Factories and Other Places of Work law (37).

Similar studies done in steel mills in Nigeria (48) and Indonesia (42) showed noise intensity levels of 49 to 93dBA and 60.4 to102 dBA respectively. Noise intensity levels at administration unit of our study industry are higher than the Rivatex textile industry, Eldoret, Kenya (5) and the steel rolling mill in Nigeria (48) but similar to the steel factory in East of Java, Indonesia (42). Noise intensity levels at the production unit of our study are lower than the steel mill in Indonesia (48) China (17) and Tanzania (52) respectively. This perhaps can be due to newer machines with frequent service and maintenance in this mill as reported by the mill owner.

In this study 39 (34.2%) workers had developed NIHL as per the Dobie criteria (32). The prevalence was high compared to similar Kenyan studies by Anino et al. (15.3%) (41), OED Jua Kali workers (22%) (6), Gitau et al (32.5%) (5) and a metallurgical company in Rio de Janeiro, Brazil (15.9%) (46).

This high prevalence may have been attributed to lack of a standard hearing conservation program other than the use of HPDs. However, it was much lower than those reported among industry workers in Malaysia (83%)(54) ,sawmill workers in Kota Bharu, Kelantan (80%) (55), and nickel workers in Zimbabwe (37%) (39).

The boilers notch has been recognised as a clinical sign of continuous exposure to noise. Barry (56) defined ONIHL as beginning at 4 KHz and then shifting towards other frequencies. All 39 workers with NIHL were found to have a notch on their audiogram with the rate highest at frequency of 4 KHz, similarly noted by Ologe et al (48) and Anino et al (41). The 3 KHz notch was seen in 4 furnace workers who had been factory workers for a minimum of 15 years, and one mill supervisor who had been a factory worker for 27 years. The shift can be explained by the lengthy period of noise exposure. Similar 3 KHz notch (24%) as well as 6 KHz notch (34%) was seen among ground crew members in the study by Anino et al (41).

In this steel mill, we found that being a production unit worker had an increased risk of 5.5 times compared to that of a non-production worker in developing NIHL thence indicating a significant difference between the two groups ($p< 0.0001$) .The production unit workers had a prevalence of 28.94% compared to non-production unit workers with 5.26%. Similarly, Shakrateh et al. (45) who did a comparative cross-sectional study in 1999, showed 30% in exposed and 8% in non-exposed, with a 4 times the risk. Ahmed et al. (44) in Saudi Arabia showed an 8-fold risk while Chang et al. (43) defined a 100 times risk between the two groups.

The 6 non production workers found with NIHL working in safe sound levels in areas normally thought to be free from noise. This maybe because those affected by NIHL are usually rotated to the noise free areas to prevent further exposure. It appears that a number of administration workers may have been subsequently promoted from production units as well as some carry out supervision of production of workers in the production environment. This may explain the hearing loss despite working in safer noise zones of 60 dBA.

All production unit workers surpassed their maximum exposure time in regards to their sound levels as per OSHA (29 CFR 1910.95) (35) as seen in Table 1. This confirms that exposure to high intensity of sound over a period of time predisposes to hearing loss. They were already candidates for hearing conservation programs stated by both OSHA (35) and the Factories and Other Places of Work law (37).

Only 15(13.2%) of all the workers reported having gone through a pre-employment hearing assessment. Due to lack of a pre-employment audiogram, the hearing loss was difficult to attribute to the current job or previous work as also reported by Ologe et al (48) and Anino et al (41).

As per U.G Olero et al (57), hearing thresholds for workers increase with both age and duration of employment. There was a positive and linear relationship between duration of noise exposure and hearing loss ($p = 0.003$). In our study all subjects had a minimum of 5 years employment duration. Cumulative length of exposure to occupational noise of above 30 years had the highest prevalence of 66.7% This relationship was also observed in the study by Shakrateh (45) that showed staff who worked over 25 years had 40% hearing loss as compared to those who worked 5-14 years suffering from a total hearing loss of 30%.Guerra (47) showed noise exposure of 20 years and above had a prevalence of 38.7%. However, Anino (41) reported that 12.1% of NIHL in crew members who had been working for more than 20 years compared to 21.4% for 0-4 years of employment.

This study shows there is possibly an additive effect of noise and age on hearing loss as stated by Dobie (29) as 58.8% of the workers above 40 years developed hearing loss. This relationship is similar to the study done by Rachiotis et al. (58) who found that workers over 40 years of age had 5.3 odds of developing NIHL compared to their younger counterparts. Guerra et al. (47) also found that subjects between the ages 30 and 39 years had 1.3 odds, those between the ages of 40 and 49 years had 6.0 odds and workers over 50 years of age had 21.3 odds of developing NIHL. Gitau et al. (5) noted that 39.6% workers above 35 years of age had a threshold shift towards hearing loss, whereas Anino et al. (41) reported a 13.7 times relative risk of developing NIHL who were aged between 20 to 29 years. In this study, all 7 individuals above 50 years of age were present in the safer administration zone throughout this study.

Workers with an upper level of education were perhaps protected from excessive noise levels as a result of deployment to administration unit seen in our study.

NIOSH (36) recommends a de-rating of 50-70% for earplugs and 25% for earmuffs. There was no significant difference in mean hearing threshold level between those who used HPDs and those who were not ($p = 0.088$) .This can be attributed to the workers noncompliance due to ignorance and incorrect use.

There are various reasons why workers exposed to loud sound refuse to wear protective devices. In our study, the 24.6% who used HPDs, 14.0% were worried they would not hear danger signals, 0.5% reported no education on how to utilize these devices and 1.8% felt hot while wearing the devices. Some administration workers, who were supervisors, periodically visited the production units to monitor the staff.In spite of a basic knowledge of HPDs, both Masaka(39) and Minja et al (52) still showed hearing loss among workers similar to the finding in our study.

A total of 19(16.7%) of all workers developed tinnitus which was lower compared to studies done by Barrs et al (58%) and Mrena et al(67.7%) (59, 60).These higher values can be attributed to a longer period of exposure of 21.8 years and 24.8 respectively.

24. CONCLUSION

It is noted that exposure to loud noise is an occupational hazard in steel mills causing NIHL among workers. The duration and intensity of noise exposure were the major risk factors in developing ONIHL and preventive strategies such as HPDs were available but only a few workers used them optimally. Poor compliance of HPDS can lead to higher prevalence of NIHL in the future.

The actual NIHL level could be higher than observed in this study due to the "healthy worker effect". Workers who may have been suffering from severe hearing loss might have actually left the factory, leaving healthier workers behind, therefore producing an underestimation of the magnitude of the problem.

The findings of this study qualify for implementation of an effective hearing conservation and rehabilitation policy that will protect and improve the quality of life of these factory workers.

25. RECOMMENDATIONS

- Provision of a pre-employment audiogram along with subsequent annual hearing assessments are highly recommended as per the Factories and Other Places of Work law (34).This will assist in recognizing and monitoring the worsening trend of ONIHL as well as enable compensation.
- Create more awareness of both the disease and prevention through government policies
- Encourage hearing conservation activities -persistent education and training is essential in high noise exposure sites of more than 85 dB (A) such as our production unit.
- Machines should be regularly maintained, inspected, and calibrated to noise emission prevention and control. The mill supervisors are encouraged to regularly purchase newer, quieter equipment.
- More periodic shift rotations and regular breaks among the different production units.
- Regular and correct use of HPDs is encouraged. Poor use of HPDs calls for a detailed KAP study in the future.
- A future study on effect of age on hearing loss in a factory setting

26. LIMITATIONS

- Previous employment history did not define the exact noise levels and duration of hours exposed during their work.
- Some supervisors were noted to shift from their units towards the production units as they monitor their staff. The noise levels and duration of exposure may not be exact.

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APPENDIX 1: GENERAL PATIENT INFORMATION AND CONSENT FORM

A greeting, my name is Dr. Mandeep Chauhan, I would like to seek your consent to participate in a study aimed at undertaking the nature of your work on your hearing. I would like to know the effect of noise on your hearing.

I will ask questions on complains you have. I will examine the ear. I will do hearing tests on you. Syringing will be done if necessary

What I propose to do is part of what is done in the course of usual examinations and investigations. No investigation will be administered to you other than that which is required to reach the diagnosis. All information will be kept confidential. The study does not reveal individual identity

You are free to drop out of the study at any time you wish so.

The information we get may not be of immediate benefit to you but it will help us in the long run in understanding the relation.

Like all scientific information we will share our findings with the other people undertaking similar studies. Therefore we will publish our findings in scientific journals or present them in scientific meetings.

Consent Form

Study number…………………

I hereby consent to participate in the study to determine hearing loss at our steel rolling mill.

Name of Patient	**Date**	**Signature**
Name of Researcher	Date	Signature

FOMU YA MAELEZO KWA MGONJWA NA MAKUBALIANO YA KUSHIRIKI KATIKA UTAFITI.

Maelezo kwa mgonjwa

Jambo,mimi ni Dr. Mandeep Chauhan naomba ruhusa yako kushiriki katika utafiti unaochunguza matatizo yanayojitokezea katika sehemu ya sikoi kutokana na kelele.

Tutakuuliza masuali kuhusu matatizo yako.Tutakupima.Tutafanya uchunguzi ya kusikia kwako .

Utafiti huu hautakuathiri kwa hali yoyote;Vipimo utakavyofanyiwa ni vile vile kama atakavyofanyiwa mgonjwa yeyote mwenya shida kama yako.

Hautafanyiwa vipimo zaidi ya vile vinavyohitajika katika kujua matatizo yako.Matokeo yote yatakuwa ni siri.Utafiti huu hautatooa kielelezo cha mgonjwa. Kama hukuridhishwa na sehemu au utafiti wote huu, uko na hiari ya kukataa.

Matokeo ya utafiti huu inawezekana usikusaidie wewe binafsi lakini yatatumika katika kusaidia wagonjwa wengine.Matokeo ya utafiti huu yatatumika kutoa taarifa kwa madaktari wanaofanya utafiti kama huu,hivyo huenda yatachapishwa katika majarida ya kisayansi.Matokeo haya hayatatumiwa kukuathari.Siri zako hazitafichuliwa.

Kama umeridhika na maelezo yetu juu ya utafiti huu,tafadhali weka sahihi/kibali chako hapo cini kwenye fomu;

Utafiti namabari…………………………

Nimekubali kushiriki katika utafiti unaochunguza matatizo yanayojitokezea katika sehemu ya sikio kutokana na kelele kwa kampuni ua kutengeneza chuma.

Jina la Mgonjwa	**Tarehe**	**Sahihi**
Jina la Mgonjwa	Tarehe	Sahihi

APPENDIX 2: QUESTIONNAIRE

No……………………………….. Date………………………………

Time………………………………….

SECTION A

PERSONAL DETAILS

Initials………..Age………Sex: M………F……… Education…………………………..

SECTION B

OTOLOGICAL HISTORY

1. Have you ever had an audiogram done? Yes ☐ No ☐

If yes, when was it done? ……………………………

2. Do you experience any ear problems? Yes ☐ No ☐

If yes, is it

a) Pain If Yes, RE ☐ LE ☐ Both ☐

b) Difficulty hearing spoken communication in one-to-one conversation? ☐

c) Difficulty understanding spoken communication in the presence of surrounding noise. ☐

d) Ringing in ears… Yes ☐ No ☐

e) Other………………………………………………………………………

3. Have you been treated for any ear infection recently? Yes ☐ No ☐

If yes, with pus ☐ No pus ☐ Duration ☐

4. Have you ever had surgery on your ears? Yes ☐ No ☐

If Yes, which surgery…………………………

SECTION C

PREVIOUS NOISE EXPOSURE HISTORY

5. Besides this current job, have you ever worked in any environment with excessive noise level

Yes ☐ No ☐

If Yes, duration…………………………

SECTION D

WORK ENVIRONMENT

6. Task…………………………………… Work Site………………Noise Level …………….

7. Length of service in this task (years) ☐ Number of working hours per day ☐

Number of working days per week ☐

8. How would you describe the type of noise that you are exposed to in your work environment?

a) Continuous (nonstop) ☐

b) Intermittent (irregular or broken) ☐

c) Impact (banging) ☐

9. How would you describe the noise levels at your work site?

Negligible ☐ Low ☐ High ☐ Very High ☐

10. Do you take any breaks in between working hours? Yes ☐ No ☐

If Yes, for how long? ☐

11. Do you do any other task with excessive noise after work? Yes ☐ No ☐

If Yes, specify……………………………

SECTION E

USE OF HEARING PROTECTIVE EQUIPMENT

12. Do you use any protective equipment for ears? Yes ☐ No ☐

If yes, duration…………

State equipment.

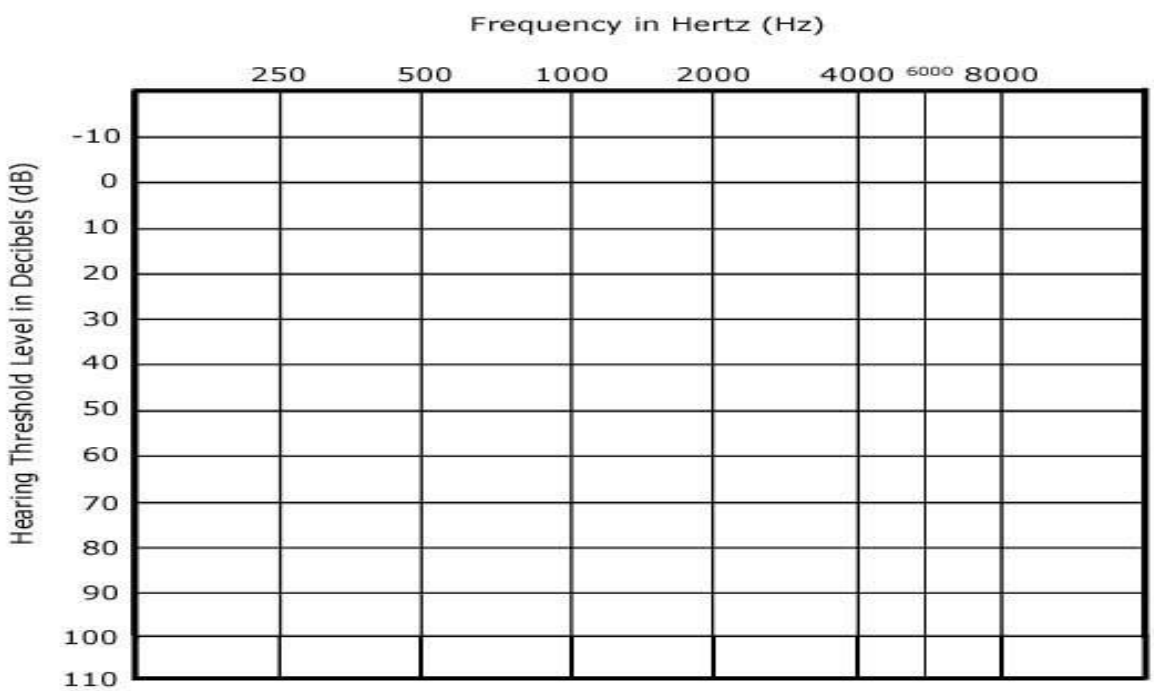
Premolded earplugs ☐ Formable earplugs ☐ Earmuffs ☐

APPENDIX 3: EAR EXAMINATION

Otoscopy	Normal	☐	Wax	☐	Other	☐
Wax removal	Yes	☐	No	☐	Other	☐
Right Ear	Rhinnes +ve	☐	Rhinnes –ve	☐		
Left Ear`	Rhinnes +ve	☐	Rhinnes –ve	☐	Weber	☐

AUDIOGRAM

No……………………………….. Date………………………………



COMMENTS: