EFFECT OF EXCESSIVE NOISE EXPOSURE ON GRANITE FACTORY WORKERS.

BY

Dr. ASHWINI PRIYANKA.V, MBBS

DISSERTATION SUBMITTED TO THE

SRI DEVARAJ URS ACADEMY OF HIGHER EDUCATION & RESEARCH,

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IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF MEDICINE
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Under the guidance of

DR. KARTHIYANEE KUTTY. MD

DEPARTMENT OF PHYSIOLOGY
SRI DEVARAJ URS MEDICAL COLLEGE, KOLAR

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PROFESSOR, HEAD OF THE DEPARTMENT

DEPARTMENT OF PHYSIOLOGY,

SRI DEVARAJ URS MEDICAL COLLEGE, KOLAR

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DATE: SIGNATURE OF THE GUIDE

PLACE:KOLAR

DR.KARTHIYANEE KUTTY, MD
PROFESSOR & HOD
DEPARTMENT OF PHYSIOLOGY

ENDORSEMENT BY THE HOD, PRINCIPAL/HEAD OF THE INSTITUTION

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DEPARTMENT OF PHYSIOLOGY.

SEAL & SIGNATURE OF THE HOD

Dr. KARTHIYANEE KUTTY

DATE:
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LIST OF ABBREVIATIONS

ONIHL	-	Occupational Noise Induced Hearing Loss
AC & BC	-	Air Conduction & Bone Conduction
Hz	-	Hertz
SPL	-	Sound Pressure Level
dBA	-	Decibel, SPL measured with “A” weighting network
PTA	-	Pure Tone Average
PPE	-	Personal Protective Equipment

ABSTRACT

Background:

Many workers are exposed to noise in their work places. Noise is a major health threat in occupations where its level exceeds the permissible level of 90dB. Noise induced hearing loss is an irreversible disease, where in increase in threshold of hearing first appears in high frequencies (4000 Hz to 6000 Hz) and is then expanded to speech frequencies (500 Hz-3000 Hz) in later phases which further leads to verbal communication disorders and ultimately functional loss. Hearing loss can be assessed using several methods like pure tone audiometry, speech audiometry, auditory evoked potentials and otoacoustic emissions. Pure tone audiometry is a simple, inexpensive, universal (for comparison) procedure which aims at ascertaining if the subject has any auditory disorder and also the degree of hearing loss. In India factory workers are unaware that they are vulnerable to workplace injury, particularly one like hearing loss, which has no obvious symptoms, it is necessary to provide effective demonstrations of the future risk they are taking, hence this study is undertaken to analyze the effect of excessive noise exposure on hearing thresholds on granite factory workers in Tamaka, Kolar.

Aims and Objectives:

1. To assess the quality of hearing in granite factory workers who are exposed to continuous noise by a questionnaire.

2. To determine the prevalence of hearing loss in those exposed to continuous noise in the granite factory and compare it with the unexposed population.
3. To determine the exposure index (sound pressure level (dB) A x duration of exposure in years) in the granite factory workers and compare it with the unexposed population.

Materials & Methods:

Eighty five granite factory workers for the exposed group and eighty five administrative workers for the unexposed group were selected considering the inclusion and exclusion criteria's. After taking written informed consent they were assessed for their quality of hearing by the questionnaire. The auditory thresholds were recorded using pure tone audiometer. The parameters that were recorded were air conduction and bone conduction thresholds of both the ears at different frequencies on an audiogram chart. The resulting data was statistically analyzed.

Results:

Noise levels recorded were significantly high in the exposed group compared to the unexposed group. 11 % of the exposed group perceived their hearing to be significantly lower than the unexposed group. 44% had difficulty in hearing over phone and in a crowd, 35 % had to keep their TV volume loud and conversed loudly when compared to others in their families and 33% had history of tinnitus compared to none in the unexposed group. Granite factory workers who were exposed to loud, continuous noise showed significantly higher thresholds in both the ears at 4000 Hz and 6000 Hz than the unexposed population. The Sound pressure level (dBA) that was recorded showed that it

was highest at the drilling section, and then the cutting section, and then the polishing section of the granite factory. There was a significant positive correlation between the sound pressure levels in various sections of the factory and the auditory thresholds of the workers and also a significant positive correlation between the number of years of exposure to noise and the auditory thresholds in these workers. The exposure index {noise level (dBA) x duration of exposure to noise in years} of the exposed group also showed a significant increase compared to the unexposed group.

Conclusion:

In our study we have found that the granite factory workers were exposed to sound levels as high as 105 dB(A) which is very much above the accepted sound levels set by the factories act 1948 in these industries. The workers had an increase in auditory thresholds at 4000 Hz and 6000 Hz which is a classical sign of ONIHL. We also found that as the number of years of exposure increased their auditory thresholds also increased, initially at the higher frequencies and later progressed to the speech frequencies leading to a decline in the quality of life of these workers. We also found that, the greater the intensity of sound shorter was the duration required for the onset of hearing loss. Thus it is suggested to implement the use of PPEs(Personal Protective Equipments) like ear plugs , ear muffs and not only should these PPEs be made available, but also periodic health checkups (audiometry) and workshops should be carried out to motivate the subjects for their correct and regular usage, and duty scheduling has to be done for exposure limitation.

Key words: Noise exposure, Auditory thresholds, Pure tone audiometry.

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INTRODUCTION

INTRODUCTION

Noise is an invisible but insidious form of pollutant, which is increasing rapidly with the advancement in industrialization. Physiologically noise is defined as a signal that bears no information and whose intensity varies randomly in time. Psychologically noise irrespective of its waveform is unpleasant and unwanted.[1] Excessive noise exposure can cause both auditory and extra auditory effects. The most important of these is hearing damage resulting from prolonged exposure to excessive noise; another undesirable effect is speech interference or interruption of communication. Annoyance is a third undesirable effect of noise.[2] Industrial noise levels not only affects the turnover and the profit margins but also causes annoyance and contributes to Occupational Noise Induced Hearing Loss (ONIHL),Psychological stresses, leads to social isolation, excessive anxiety, irritability and low self esteem in workers exposed to these noise levels each day and over a period of time.[3,4,5] ONIHL causes problems not only for the individuals concerned but also for their families and co-workers.[6, 7]

ONIHL is defined as partial or complete hearing loss in one or both ears as the result of one's employment. World Health Organization (WHO) describes that exposure to excessive noise is the major avoidable cause of permanent hearing impairment .[8] Occupational Noise Induced Hearing Loss (ONIHL) is the second most leading cause of hearing loss after age-related hearing loss.[9] 16 % of the hearing loss in adults worldwide is attributed to occupational noise exposure.[10] Various studies have shown that people exposed to noise level above 85 dB(A) suffered from ONIHL.[9] Recent estimates indicate that hearing loss greater than 25 dB(A) in the human hearing frequencies is regarded as a significant hearing disability by WHO.[11] The damaging effect on hearing depends on the level and spectrum of the noise, duration of exposure to noise , how many hours in a day they are exposed , over how many years daily exposure is repeated and individual susceptibility to this type of injury. [12] The highest attributable fraction of adult-onset hearing loss resulting from noise exposure in the world comes from Asian countries. ONIHL is a serious health problem in Asia, not only because of increasing number of affected laborers, but also because the majority of Asian countries are still developing economies where access to health services and preventive program are limited. Lack of awareness about ONIHL among employers, employees in these industries like the granite factories is one of the main barriers for the prevention of ONIHL in Asia. [13]

As per Dobie's criteria ONIHL is a sensorineural and progressive hearing loss with loss always being more at 3000-6000 Hz than 500-2000Hz. [5] Traditionally loud noise produces an audiometric notch at 4000Hz known as "Aviator's Notch".[13,14] However few studies showed notch at 6000Hz.[15,16] This notch typically develops at one of these frequencies and affects adjacent frequencies with continued noise exposure.[17,18] The higher the intensity of sound the shorter is the duration required for the onset of hearing loss.[19] The temporary threshold shift (TTS) is a temporary increase in the hearing threshold caused due to the exposure to loud noise that recovers almost completely within 24 hours of non exposure. However, repeated insults of excessive noise can transform this TTS into a permanent threshold shift.[12, 20] Thresholds may fully recover in TTS or stabilize at an elevated value ("permanent" threshold shift). NIHL is due to destruction of cochlear hair cells or damage to their mechano-sensory hair bundles caused by continuous noise exposure of > 85dB (A) for 8 hours at the work place. [21]

Granite stone quarrying is the most common occupation of many workers in Kolar district, belonging to Karnataka state in India. In India, ONIHL has been a compensable disease since 1948. It is only in 1996 that the first case got compensation.[8] The quality of life of industrial worker is one of the prime factors for production; hence it should not be neglected.

The workers in the granite factories are victims to the hazards of excessive noise exposure at the work place .[2] Even though ONIHL is preventable; there is no evidence that this is realized in practice. Better implementation and reinforcement of protective measures is needed. In India only few studies regarding the estimation of noise levels in the granite factories and auditory effects in workers due to noise exposure at these granite factories are available. This may be one of the reasons for the unawareness of the noise hazards in this group of workers. We are currently reaping the hazards of this unwanted increase in noise in these industries which is incurable, but surely preventable. Hence this study is aimed to study the effect of noise exposure on the granite factory workers in and around Kolar district.

AIMS AND OBJECTIVES

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1. To assess the quality of hearing in granite factory workers who are exposed to continuous noise by a questionnaire.
2. To determine the prevalence and type of hearing loss in those exposed to continuous noise in the granite factory and compare it with the unexposed population.
3. To determine exposure index [sound pressure level dB (A) x duration of exposure in years] in the granite factory workers and compare it with the unexposed population.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A. HISTORICAL REVIEW:

Man's discovery of the metals with the attendant noises of heating, hammering occasioned perhaps the first situation in which human hearing was 'at risk' from occupational noise. The second danger was the gun powder which appeared at about 1300 AD. The next threat was associated with industrial revolution and the mechanization of factories. It is little recognized that after Second World War there was further industrial revolution in which the results of technological and scientific discovery that started were put into effect and which continues to the present day.

Refineries, chemical plants, paper making machinery, mining equipment, construction machinery, transportation vehicles, all these industries became larger, more efficient and contributed to a large proportion of industrial noise. Recognition that deafness could be caused by noise was slow, although some of its effects on the ear were obvious. The first mention of deafness from cannonading is attributed to Alberti in 1591 who reported that workers who hammered copper for a living had their ears so injured by the perpetual din that they became hard of hearing .If they lived to an old age and continued to work , they became completely deaf. He recommended the use of hearing protectors to prevent deafness. Fosbroke in 1831 gave an accurate description of noise induced deafness in blacksmiths and coined the expression 'blacksmiths deafness'.

In 1886,Thomas Barr introduced the term boilermakers deafness. The site and nature of the lesion in the ear produced by noise was first described by Haberman in 1890 in a man aged 75yrs who had worked as a blacksmith for 20 years and whose occupation had exposed him to high intensity noise during working life. He reported that there was a partial disappearance of the organ of corti with destruction of the hair cells with the most extensive damage being in the lower basal coil. There was a resultant atrophy of the auditory nerve, with complete degeneration of the spiral ganglion and the nerves in the osseous spiral lamina. Soon after the introduction of audiometry, Fowler in 1939 observed dips at 4000Hz and Bunch published the first audiometric data demonstrating the typical high frequency loss acquired by those exposed to noise.

In 1890 the world's first Society for the Suppression of Noise was formed in London. Its principal target was the newly-invented motor horn. In 1960 John Connell's Noise Abatement Society for the first time through the Noise Abatement Act succeeded in having noise accepted as statutory nuisance.

In 1972 the noise control act was passed by the United states of America which was revised by the Occupational Safety and Health Administration of the US in 1983 which adopted a permissible exposure limit of 85dB (A) for an 8 hr, time weighted, average noise exposure, and higher exposure levels of 115 dB (A) for progressively shorter durations, and notified that a hearing conservation program had to be implemented if the noise exposure exceeded 85dB (A).

In 1976 the Indian government included NIHL as a notifiable disease. In the year 2000, rules for the Regulation and Control of noise pollution stated that the permissible noise exposure level for industrial workers is 90 dB (A) for a period of 8 hours and exposure to continuous or intermittent noise louder than 115 dB (A) should not be permitted. Exposure to pulse or impact noise should not exceed 140 dB (peak acoustic pressure).

The historical antecedents of pure tone audiometry used to measure auditory thresholds were the classical tuning fork tests. The development of the audiometer made it possible to control signal intensity and duration in ways that were not possible with tuning forks. Pure tone audiometry was introduced for the first time in 1977 by the American Speech and hearing Association is the key hearing test used to identify hearing threshold levels at different frequencies of an individual, enabling determination of the degree, type and configuration of a hearing loss. Thus, providing the basis for diagnosis and management of hearing loss.[1]

B. ANATOMY OF EAR:

The ear is the sensory organ responsible for hearing. It is composed of three parts termed the external ear, the middle ear and the inner ear.

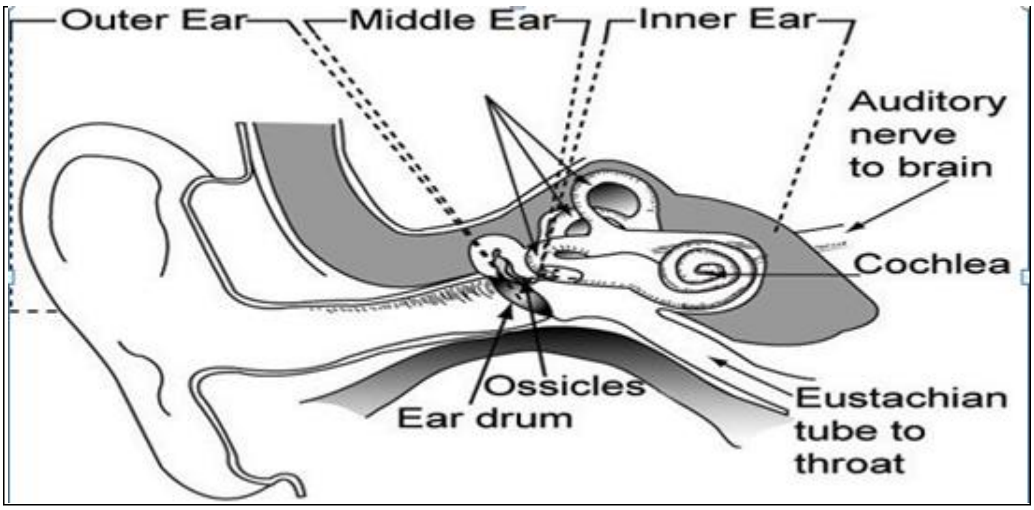


Fig 1: Anatomy of ear

External ear:

The external ear includes the auricle (pinna) and external auditory canal. The auricle is composed of elastic fibrocartilage covered by perichondrium and skin. The skin over the lateral aspect of the ear is tightly adherent to the perichondrium whereas on the medial surface, it is more loosely attached. The auricle is attached to the tympanic portion of the temporal bone on the lateral aspect of the skull by extension of the auricular cartilage into the cartilaginous external canal, by three ligaments (anterior, superior, and posterior), by six poorly developed muscles and by its skin and subcutaneous tissue.

The auricle receives sensory innervation from branches of cranial nerves V (auriculotemporal nerve), VII (auricular branch), X (auricular branch) and by the greater auricular nerve from the cervical plexus. Blood supply to the auricle is from the external carotid system mainly by way of the posterior auricular artery and superficial temporal artery. The external auditory canal extends from the concha I cartilage of the auricle to the tympanic membrane. It is approximately 25 mm long in the adult. It courses slightly anteriorly and inferiorly in the adult. The outer l/3rd of the canal is cartilaginous, has thicker skin with subcutaneous tissue and ceruminous glands. The inner 2/3rd is osseous with only epidermis lying on the periosteum of the bony external canal. [22]

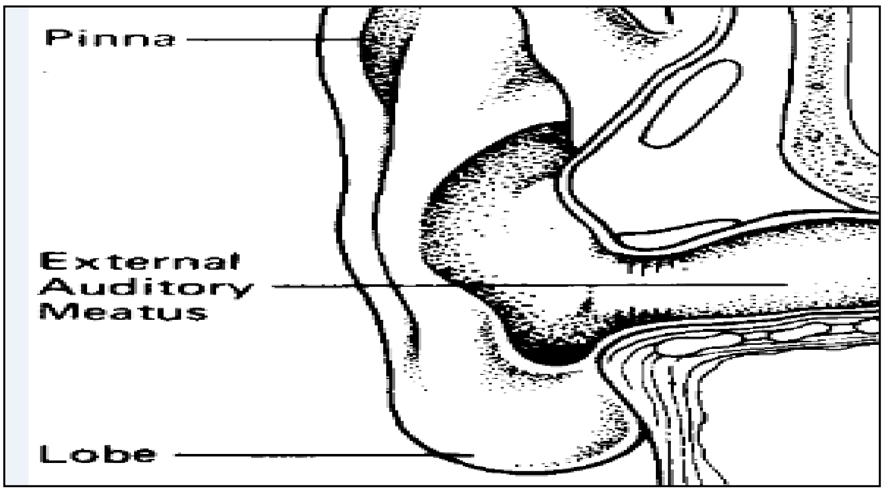


Fig 2: Structure of External ear.

Middle ear:

The middle ear is composed of the tympanic membrane, the tympanic cavity, the ossicles and the eustachian tube. The tympanic membrane forms the lateral wall of the middle ear. It is oval in shape, approximately 8 mm wide and 10mm high. The tympanic membrane is about 0.1 mm thick and lies at an angle of 40 degrees in the sagittal plane with the lower aspect displaced medially. It is not flat, rather it is concave medially. The umbo marks the middle of the tympanic membrane and corresponds to the attachment of the tip of the malleus to the tympanic membrane.

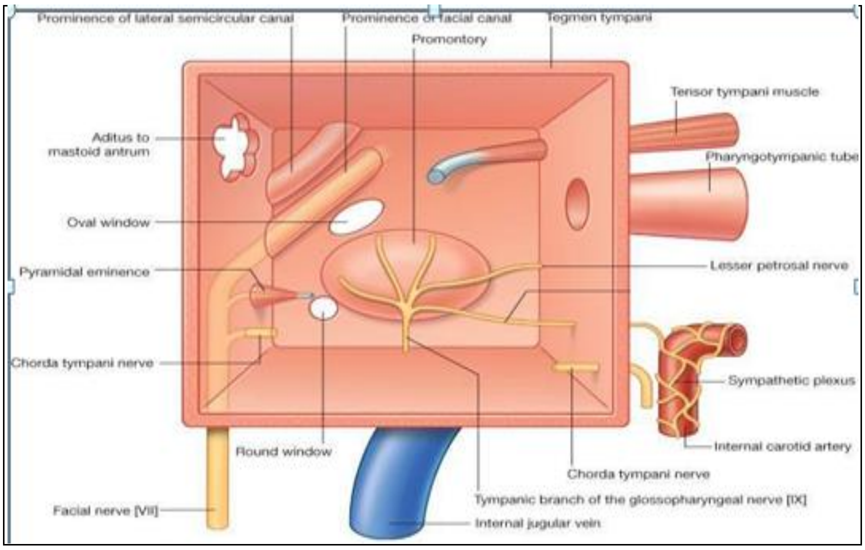


Fig 3: Boundaries of middle ear

The boundaries of the middle ear is formed by the short process of the malleus superiorly which extends laterally and forms a prominence on the tympanic membrane. From this prominence extend the anterior and posterior malleolar folds. Superior to the folds, lies the pars flaccida (or Shrapnell's membrane), below is the pars tensa. The pars tensa inserts into a bony groove in the tympanic bone termed the tympanic sulcus. The tympanic membrane is composed of three layers, an outer layer of epidermis continuous with the epidermis of the external auditory canal, a middle layer of fibrous tissue (lamina propria) and a medial layer of mucosa. Sensory nerves to the tympanic membrane include the auricular branch of cranial nerve X and the auriculotemporal branch of the mandibular nerve. The blood supply to the tympanic membrane arises from vessels from the external maxillary artery and the stylomastoid artery. The tympanic cavity is a cleft or space within the temporal bone located between the tympanic membrane laterally and the inner ear medially. Posteriorly it communicates with the mastoid air cells and anteroinferiorly with the eustachian tube orifice. Within the cavity are present the middle ear ossicles, the chorda tympani and a segment of the facial nerve (cranial nerve VII).

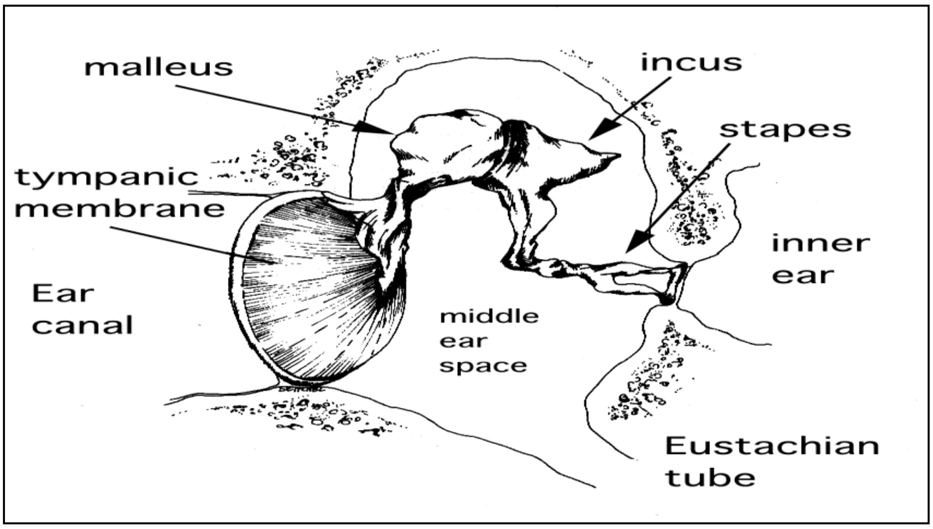
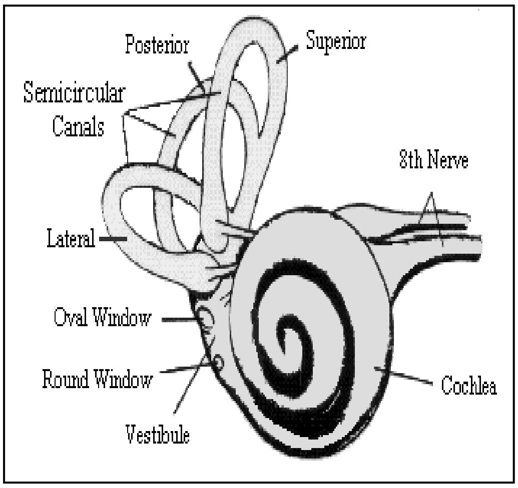


Fig 4: Middle ear bones

The middle ear contains three bones or ossicles which transmit sound vibrations to the inner ear. They are from lateral to medial, the malleus, the incus and the stapes. The malleus is firmly attached to the tympanic membrane and the stapes sits within the oval window of the cochlea. Between them lies the incus. The ossicles are held in place by their attachments mentioned above, by their joints with each other, by ligaments and two muscles; the tensor tympani to the malleus and the stapedius muscle to the stapes.[24]

Inner ear:

The inner ear consists of two main parts, the cochlea (end organ for hearing) and the vestibule and semicircular canals (end organ for balance). The inner ear can be thought of as a series of tunnels or canals within the temporal bone. Within these canals are a series of membranous sacs (termed labyrinths) which house the sensory epithelium. The membranous labyrinth is filled with a fluid termed endolymph; it is surrounded within the bony labyrinth filled by a second fluid termed perilymph. The cochlea can be thought of as a canal that spirals around itself similar to a snail. It makes roughly 2 1/2 to 2 3/4 turns.[23]



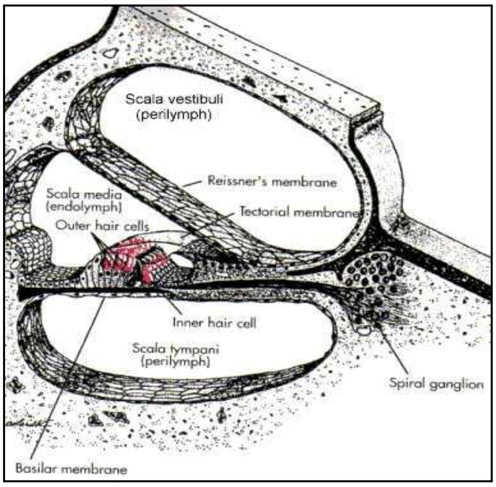


Fig 5: Parts of Inner ear.

Fig 6: Cross section of the Cochlea.

The bony canal of the cochlea is divided into an upper chamber, the scala vestibuli and a lower chamber, the scala tympani by the membranous (otic) labyrinth also known as the cochlear duct. The scala vestibuli and scala tympani contain perilymph.

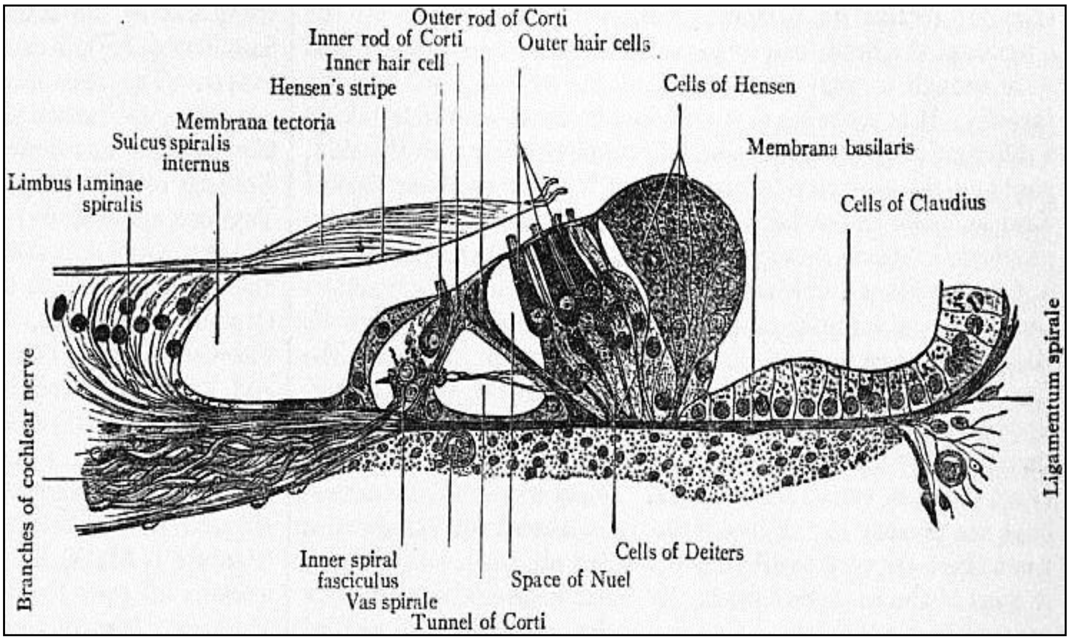


Fig 7: Structure of Scala Media.

The scala media contains endolymph. Endolymph is similar in ionic content to intracellular fluid (high K^+, low Na^+) and perilymph resembles extracellular fluid (low K^+, high Na^+). The cochlear duct contains several types of specialized cells responsible for auditory perception. The floor of the scala media is formed by the basilar membrane, the roof by Reissner's membrane. Situated on the basilar membrane is a single row of inner hair cells medially and three rows of outer hair cells laterally. The cells have specialized stereocilia and kinocilia on their apical surfaces. Attached to the medial aspect of the scala media is a fibrous structure called the tectorial membrane. It lies above the inner and outer hair cells coming in contact with their stereocilia. Synapsing with the base of the hair cells are dendrites from the auditory nerve. The auditory nerve leaves the cochlear and temporal bone via the internal auditory canal and travels to the brainstem.

Structure of Hair Cell:

Hair cells are the sensory receptor cells of hearing and balance and are the most important cells in the inner ear. Their name derives from the fact that they have about 100 stereocilia at their apical end. Individual stereocilia are packed with a filamentous actin cytoskeleton. Hair cells are specialized mechanoreceptors that convert the mechanical stimuli associated with hearing and balance into neural information for transmission to the brain. The process of conversion of one type of energy to another is called transduction.[24]

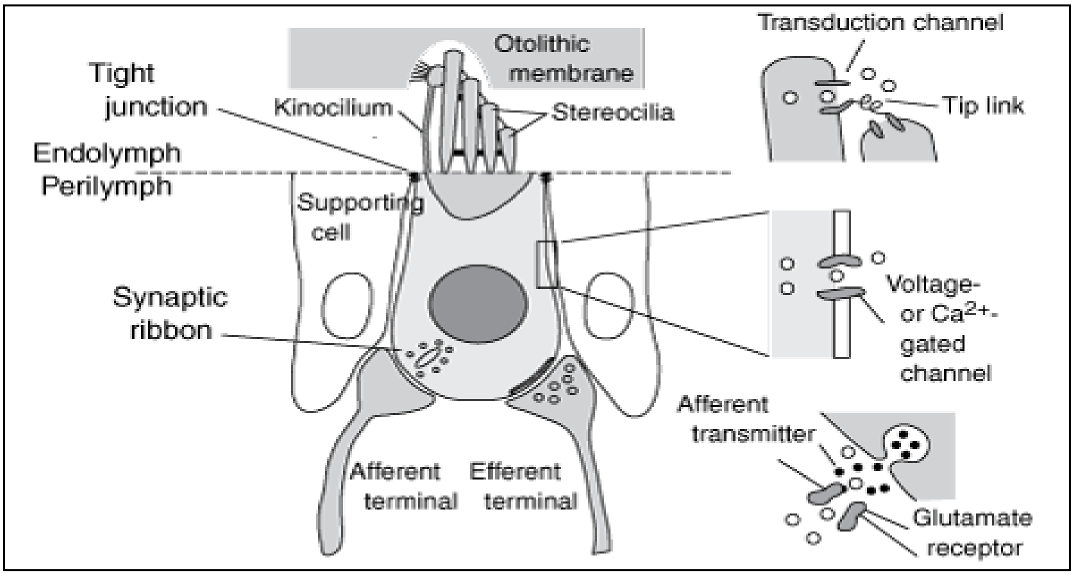


Fig 8: Structure of an auditory receptor (Hair cell).

The stereocilia of each hair cell are arranged in a precise geometry. This arrangement is asymmetrical and polarized because the stereocilia are arranged in rows of short, intermediate, and tall stereocilia. A single kinocilium is located adjacent to the tallest row. It has a 9 by 2 microtubule organization similar to motile cilia found elsewhere in the body. The kinocilium is thought to establish the morphologic polarization of the stereocilia bundle and is not required for mechanoelectrical transduction. It is present in embryonic cochlear hair cells but is resorbed by the time cochlear hair cells mature.[25] Very fine processes called tip links tie the tip of each stereocilium to the side of its higher neighbor, and at the junction there appear to be mechanically sensitive cation channels in the higher process.

C.PHYSIOLOGY OF HEARING

The mechanism of hearing can be broadly divided into:

1. Transmission of the sound from the external ear to the internal ear (conductive apparatus).
2. Development of action potentials in hair cells- Transduction of mechanical energy to electrical impulses (sensory system of cochlea).
3. Conduction of electrical impulses to the brain (Auditory pathway and processing).

1) Transmission of sound from external ear to inner ear:

Sound waves in the external environment that travel through the pinna and the external auditory meatus are transformed by the tympanic membrane and the auditory ossicles into movements of the footplate of the stapes.[26] The tip end of the handle of the malleus is attached to the center of the tympanic membrane, and this point of attachment is constantly pulled by the tensor tympani muscle, which keeps the tympanic membrane tensed. This allows sound vibrations on any portion of the tympanic membrane to be transmitted to the ossicles, which would not be true if the membrane were lax.

The ossicles of the middle ear are suspended by ligaments in such a way that the combined malleus and incus act as a single lever, having its fulcrum approximately at the border of the tympanic membrane. The articulation of the incus with the stapes causes the stapes to push forward on the oval window and on the cochlear fluid on the other side of window everytime the tympanic membrane moves inward, and to pull backward on the fluid every time the malleus moves outward.[26]

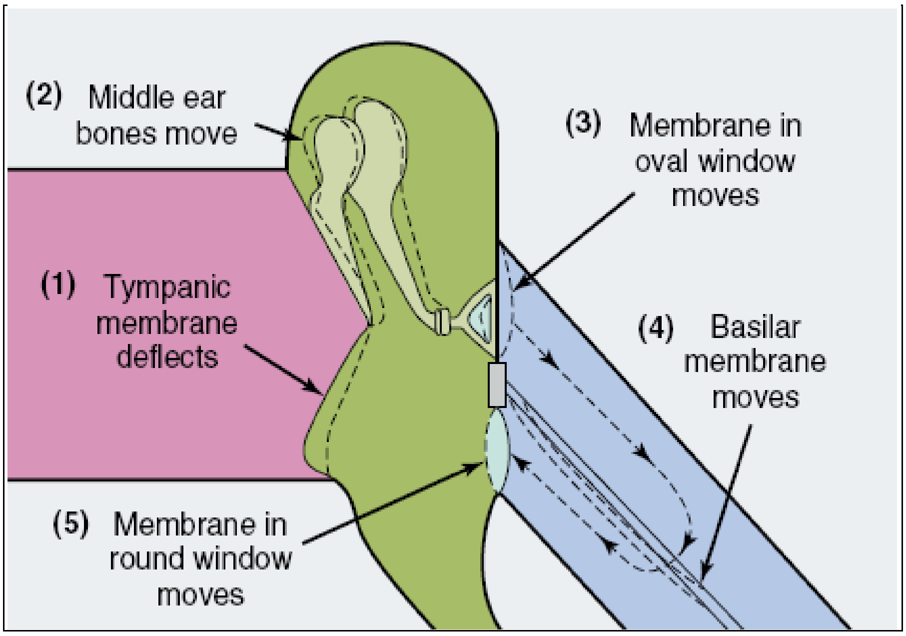


Fig 9: Transmission of sound waves through middle and inner ear.

Impedance Matching by the Ossicular System. The amplitude of movement of the stapes footplate with each sound vibration is only three fourths as much as the amplitude of the handle of the malleus. Therefore, the ossicular lever system does not increase the movement distance of the stapes, as is commonly believed. Instead, the system actually reduces the distance but increases the force of movement about 1.3 times. In addition, the surface area of the tympanic membrane is about 55 square millimeters, whereas the surface area of the stapes averages 3.2 square millimeters. This 17-fold difference times the 1.3-fold ratio of the lever system causes about 22 times as much total force to be exerted on the fluid of the cochlea as is exerted by the sound waves against the tympanic membrane. Because fluid has far greater inertia than air does, it is easily understood that increased amounts of force are needed to cause vibration in the fluid.

Therefore, the tympanic membrane and ossicular system provide impedance matching between the sound waves in air and the sound vibrations in the fluid of the cochlea. Indeed, the impedance matching is about 50 to 75 per cent of perfect for sound frequencies between 300 and 3000 cycles per second, which allows utilization of most of the energy in the incoming sound waves. [25] The movements of the footplate of the stapes sets up waves in the fluid of the inner ear which generates action potentials in the nerve fibers. Thus the ear converts sound waves into action potentials in the auditory nerves. The auditory ossicles thus function as a lever system that converts the resonant vibrations of the tympanic membrane into movements of the stapes against the perilymph filled scala vestibuli of the cochlea which sets up a series of traveling waves in the perilymph. The distance from the stapes to the point of maximum height varies with the frequency of the vibrations initiating the wave. High pitched sounds generate waves that reach maximum height near the base of the cochlea; low-pitched sounds generate waves that peak near the apex.[27]

2) Development of action potential in hair cells:

- <u>Electrical Responses :</u>

The membrane potential of the hair cells is about -60 mV. When the stereocilia are pushed toward the kinocilium, the membrane potential is decreased to about -50 mV. When the bundle of processes is pushed in the opposite direction, the cell is hyperpolarized. Displacing the processes in a direction perpendicular to this axis provides no change in membrane potential, and displacing the processes in directions that are intermediate between these two directions produces depolarization or hyperpolarization that is proportionate to the degree to which the direction is toward or away from the kinocilium. Thus, the hair processes provide a mechanism for generating changes in membrane potential that are proportionate to the direction and distance the hair moves.

As noted above, the processes of the hair cells project into the endolymph whereas the bases are bathed in perilymph. This arrangement is necessary for the normal production of generator potentials. The perilymph is formed mainly from plasma. On the other hand, endolymph is formed in the scala media by the stria vascularis and has a high concentration of K^+ and a low concentration of Na^+ .

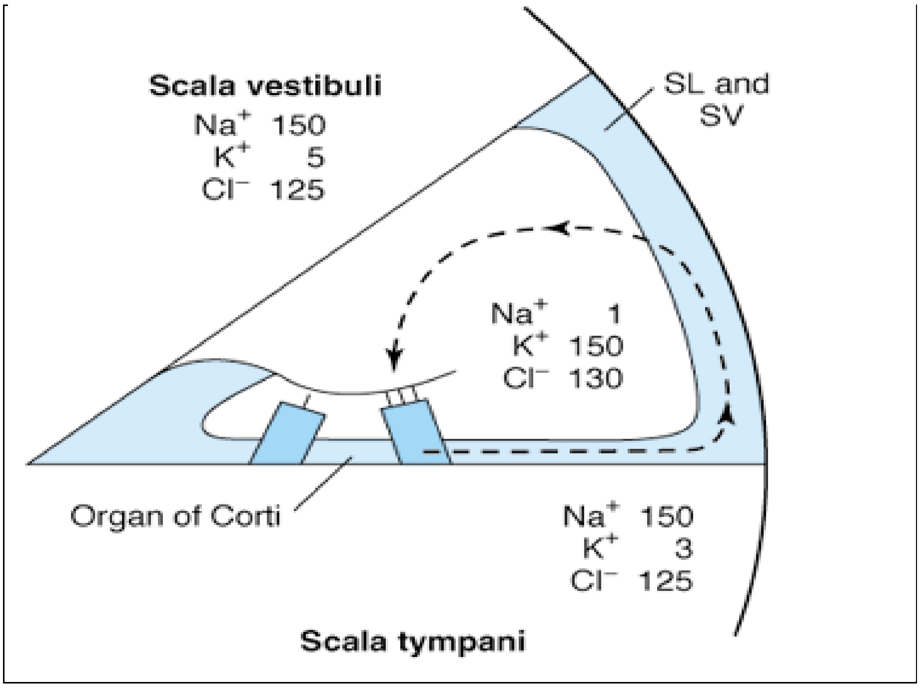


Fig 10: Ionic Composition of Perilymph and Endolymph.

Cells in the stria vascularis have a high concentration of Na^+-K^+ ATPase. In addition, it appears that there is a unique electrogenic K^+ pump in the stria vascularis, which accounts for the fact that the scala media is electrically positive by 85 mV relative to the scala vestibuli and scala tympani.[27]

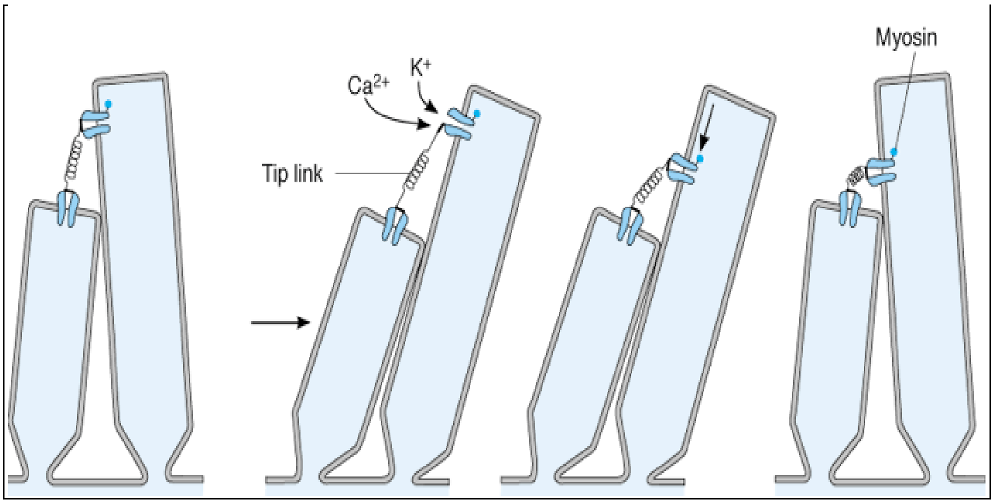


Fig 11: Movement of Stereocilia

The deflection of the stereocilia toward the tallest row causes shearing between the stereocilia, which causes the tip links to pull on the transduction channels, opening them. Deflection in the other direction releases the tension of the tip link, causing the transduction channels to close. Bending the bundle in the direction of the tallest row leads to entry of K^+ and Ca^{2+} ions into the hair cell through channels that open at the tips of the stereocilia. This causes the hair cell to depolarize. Bending the bundle in the opposite direction promotes channel closure and results in hair cell hyper polarization.

Within the stereociliary bundle, there is movement of the bundle back and forth parallel with the axis of symmetry through the kinocilium. Movement in this direction produces a maximal receptor potential (change in intracellular voltage). As the bundle is moved at larger angles away from this axis, the receptor potential is reduced.[28]

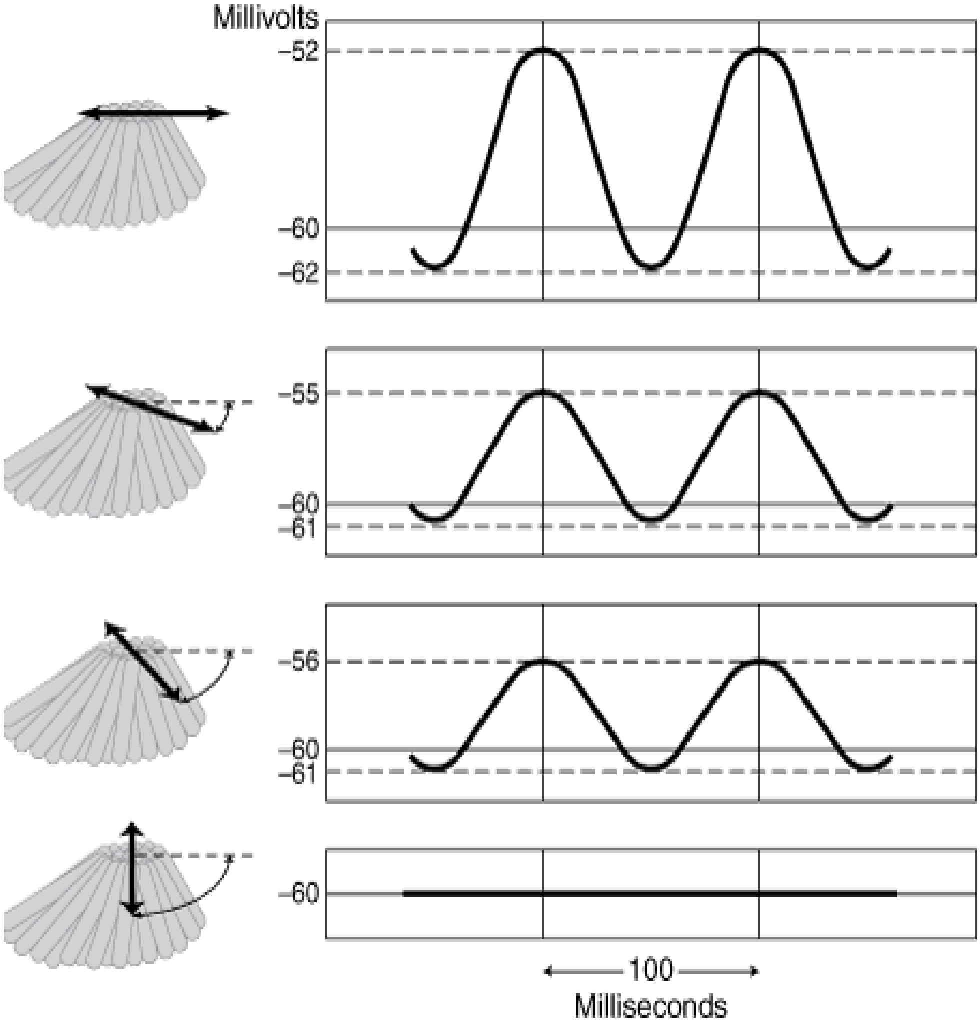


Fig 12: Receptor potential

The receptor potential is asymmetric, with larger depolarizing swings compared with hyperpolarizing swings. This is because the current-voltage characteristics of the hair cell are nonlinear and are shaped by the various voltage and calcium dependent ion channels in its basolateral plasma membrane. The above fig 12 demonstrates that deflection of the stereociliary bundle perpendicular to the bundle's axis of symmetry produces no receptor potential. [26]

- Genesis of Action Potentials in Afferent Nerve Fibers:

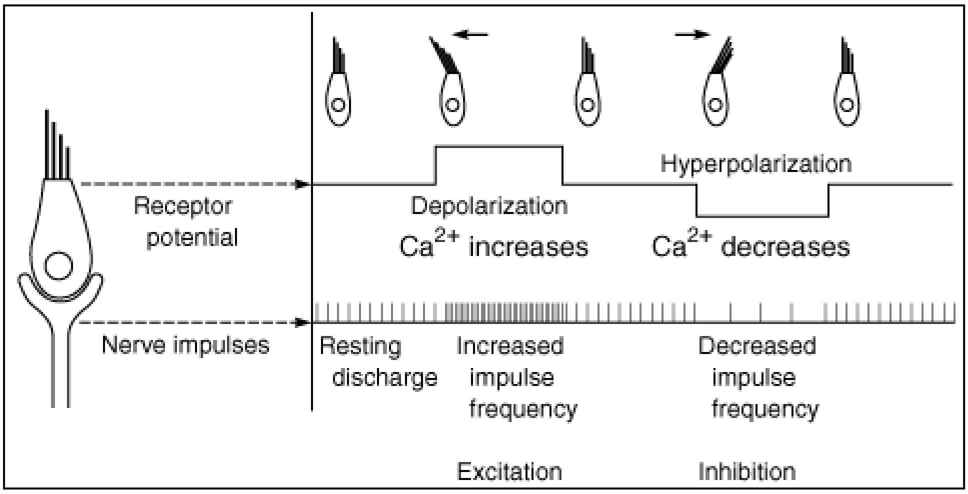


Fig 13: Genesis of Action Potential

Hair cells have synapses located at their basal pole. When a hair cell is mechanically stimulated, it releases a chemical that modulates the electric activity of the afferent neurons. This neurotransmitter release is regulated by changes in the membrane potential of the hair cell in response to bending its stereocilia bundle. Efferent synapses at the termination of the fibers originating deep in the brainstem are also present. The neural signals from the brain conveyed by these efferent fibers modulate the gain (amplification) of the hair cells they innervate. [25] When the shorter stereocilia are pushed toward the higher, the open time of these channels increases. K^+—the most abundant cation in endolymph—and Ca^{2+} enter via the channel and produce depolarization. There is still considerable uncertainty about subsequent events. However, one hypothesis is that a molecular motor in the higher neighbor next moves the channel toward the base, releasing tension in the tip link. This causes the channel to close and permits restoration of the resting state. The motor apparently is myosin-based.

The K^+ that enters hair cells via the mechanically sensitive cation channels is recycled. It enters sustentacular cells and then passes on to other sustentacular cells by way of tight junctions. In the cochlea, it eventually reaches the stria vascularis and is secreted back into the endolymph, completing the cycle .[27]

3) Auditory pathway and auditory processing:

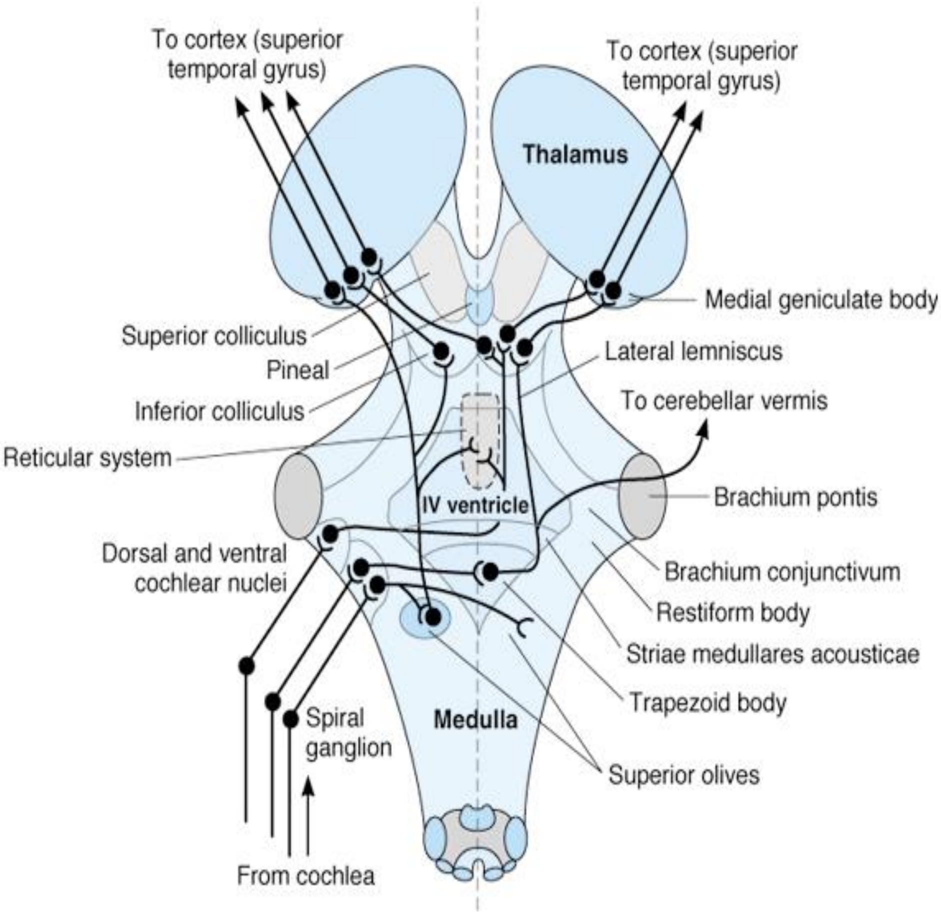


Fig 14: Central Auditory Pathway.

From the cochlea nuclei, auditory impulses pass via a variety of pathways to the inferior colliculi, the centre for auditory reflexes, and via the medial geniculate body in the thalamus to the auditory cortex. Information from both ears converges on each superior olive, & all higher levels most of the neurons respond to the inputs from both sides. The primary auditory cortex, Broadmann's area 41, is in superior portion of temporal lobe. The auditory association areas adjacent to primary auditory receiving area are wide spread. The olivo cochlear bundle is a prominent bundle of efferent fibres in each auditory nerve that arises from both the ipsilateral & contralateral superior olivary complex and ends primarily around the bases of outer hair cells of the organ of corti. Although the auditory areas look very much the same on both sides of the brain, there is marked hemispheric specialization. For example, Broadmann's area is concerned with processing of auditory signals related to speech, during language processing, it is much more on left side than right side. Area 22 on right side is more concerned with melody, pitch and sound intensity.

Sound localization:

Determination of the direction from which a sound emanates in the horizontal plane depends upon detecting the difference in time between the arrival of the stimulus in the two ears and the consequent difference in phase of the sound waves on the two sides; it also depends upon the fact that the sound is louder on the side closest to the source. Neurons in the auditory cortex that receive input from both ears respond maximally or minimally when the time of arrival of a stimulus at one ear is delayed by a fixed period relative to the time of arrival at the other ear. This fixed period varies from neuron to neuron. Sounds coming from directly in front of the individual differ in quality from those coming from behind because each pinna is turned slightly forward.

D. Theories of hearing:

1. **Von Bekesy's travelling wave theory**:

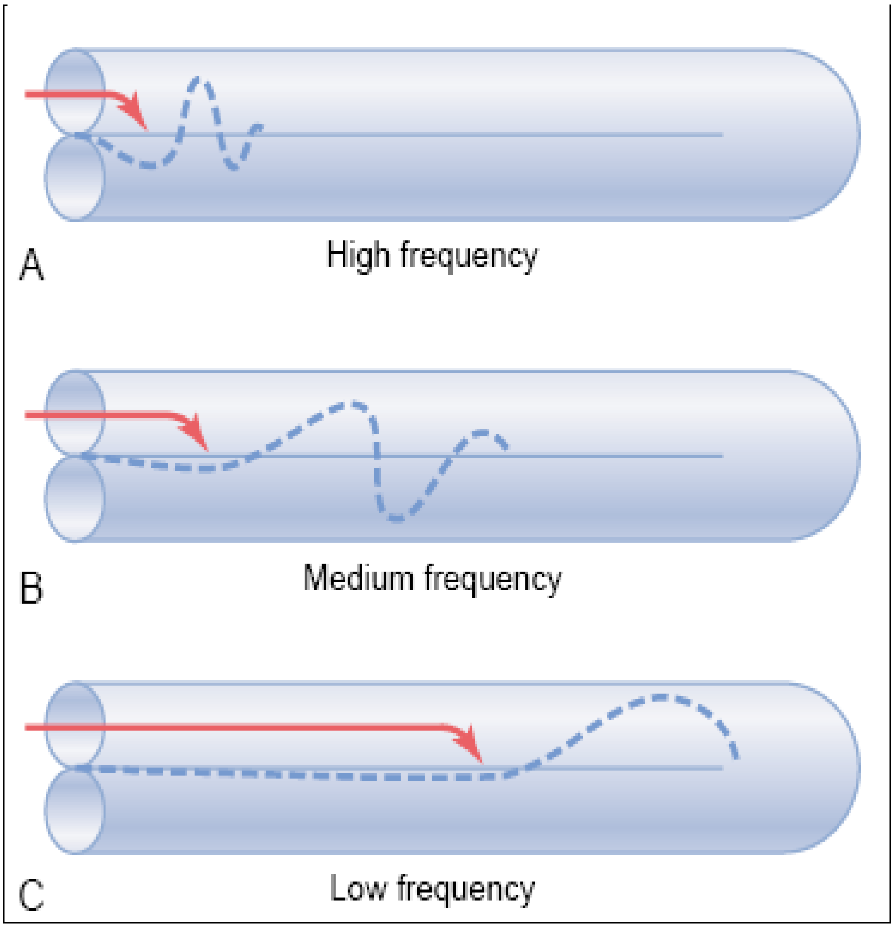


Fig 15: Travelling wave

This theory suggests that a wave of displacement progresses in a systematic way along the cochlear partition and produces a local stimulation in its path. It is for this work that Von Bekesy received a Nobel Prize in 1961.The movements of the footplate of the stapes set up a series of traveling waves in the perilymph of the scala vestibuli. As the wave moves up the cochlea, its height increases to a maximum and then drops off rapidly. The distance from the stapes to this point of maximum height varies with the frequency of the vibrations initiating the wave. High-pitched sounds generate waves that reach maximum height near the base of the cochlea; low-pitched sounds generate waves that peak near the apex. The bony walls of the scala vestibuli are rigid, but Reissner's membrane is flexible. The basilar membrane is not under tension, and it also is readily depressed into the scala tympani by the peaks of waves in the scala vestibuli. Displacements of the fluid in the scala tympani are dissipated into air at the round window. Therefore, sound produces distortion of the basilar membrane and the site at which this distortion is maximal is determined by the frequency of the sound wave.

2. **Frequency theory/ temporal theory of hearing:**

States that our perception of sound depends on the temporal patterns with which neurons respond to sound in the cochlea. Early forms of the frequency theory were sometimes referred to as telephone theories and assumed that the auditory nerve passed complete time domain representations of the incoming acoustic signal to the brain in a manner analogous to the way the waveform of a speech sound is transformed into fluctuating voltages in a telephone line. This theory assumes that a complete time domain representation of the incoming waveform is directly encoded in the pattern of firings of the auditory nerve. This theory, in this simple form, assumes that the auditory nerve can fire at rates of 20 to 20,000 times per second. This is a necessary assumption if the theory is to be able to account for the frequency range of human hearing, 20-20,000 Hz. A major premise of the frequency theories is that the frequency analysis is not carried out in the inner ear, but that a time domain representation is transmitted to the brain and the frequency analysis is carried out in the brain.

3. **Volley's Theory:**

When the frequency is low enough, the nerve fibers begin to respond with an impulse to each cycle of a sound wave. The importance of this volley effect, however, is limited; the frequency of the action potentials in a given auditory nerve fiber determines principally the loudness, rather than the pitch, of a sound. proposed by Wever and Bray (1937), attempts to account for the maximum theoretical limit for the neuronal firing of action potentials and the small time scales over which sound discrimination must occur. In this theory, the organ of corti in the cochlea that transduces the sound into action potentials must combine multiple stimuli along the cochlear nerve within a volley in order to encode high frequency auditory stimuli. "An extension of frequency theory, which proposes that when peaks in a sound wave come too frequently for a single neuron to fire at each peak, several neurons fire as a group at the frequency of the stimulus tone."

4. The Resonance or Place Theory:

The Place theory, in its most modern form, states that the inner ear acts as a tuned resonator which extracts a spectral representation of the incoming sounds which it passes via the auditory nerve to the brainstem and the auditory cortex. This process involves a tuned resonating membrane, the basilar membrane, with frequency place-mapping. In other words, each position on the basilar membrane is associated with a particular characteristic frequency (CF). A tone of 500Hz, for example, would stimulate most strongly that part of the basilar membrane which has a characteristic frequency of 500Hz. Further, this mapping of frequency to place is linearly related to frequency with CF gradually decreasing as one move from the oval window to the apex of the cochlea. This kind of frequency to place mapping is called tonotopic mapping and systems with this characteristic are said to display tonotopicity. The place encoded frequency pattern is passed to the brainstem and thence to the auditory cortex, both of which also display tonotopicity. A major premise of the place theories is that the frequency analysis is carried out in the inner ear creating a neural spectrogram that is transmitted to the brain.

E. AUDIOLOGY AND ACOUSTICS

This section aims to introduce certain terms which are frequently used in audiology and acoustics.

Sound: It is a form of energy produced by a vibrating object. A sound wave consists of compressions and rarefactions of the molecules of the medium (air, liquid, or solid) in which it travels. Velocity of the sound is different in different media. In the air, at 20° at sea level, sound travels 344 meters / sec and it is faster in the liquid and still faster in the solid media.

Frequency: It is the number of cycles per second. The unit of frequency is Hertz (Hz), named after German scientist Heinrich Rudolf Hertz

Pure tone: A single frequency sound is called a pure tone.

Pitch: It is the subjective sensation produced by the frequency of the sound. Higher the frequency greater is the pitch.

Complex sound: Sound with more than one frequency is called a complex sound. Human voice is a complex sound.

Intensity (amplitude): It is the strength of the sound which determines its loudness. It is measured in decibels. At a distance of one meter intensity of sound are

Faint = 30 dB (E.g.: whisper, library)

Moderate = 40-50dB (E.g.: normal room noise)

Very loud = 60-80 dB (alarm clock, busy traffic, conversation)

Extremely high = 90-110dB

Pain in ear = 120-160dB [27]

Decibel: It is I/I0th of a bel, and is named after Alexander Graham Bell, the inventor of telephone.

The amplitude of a sound wave can be expressed in terms of the maximum pressure change at the tympanic membrane, but a relative scale is more convenient. The **decibel scale** is such a scale. The intensity of a sound in **bels** is the logarithm of the ratio of the intensity of that sound and a standard sound. A decibel (dB) is 0.1 bel.

Formula for decibel is

Sound in decibel = 10 Log power of S l/power of S2

OR

10 Log (SPL OF S 1)2 /SPL OF S2

Sound intensity is proportionate to the square of sound pressure.

S1 =Sound being described

S2 =Reference sound

SPL =sound pressure level

Sound can be measured in watts/cm2 or dynes/cm2.

In audiology, sound is measured as sound pressure level (SPL). Noise levels are often expressed as dB(A) which refers to sound pressure level with "A" network where the low and extremely high frequencies are given much less weightage compared to those in middle range which are more important and are responsible for NIHL.

The standard sound reference level adopted by the Acoustical Society of America corresponds to 0 decibels at a pressure level of 0.000204 × dyne/cm^2, a value that is just at the auditory threshold for the average human. In the decibel levels of various common sounds are compared. It is important to remember that the decibel scale is a log scale. Therefore, a value of 0 decibels does not mean the absence of sound but a sound level of intensity equal to that of the standard. Furthermore, the 0- to 140-decibel range from threshold pressure to a pressure that is potentially damaging to the organ of Corti actually represents a 10^7- (10 million)-fold variation in sound pressure. Put another way, atmospheric pressure at sea level is 15 lb/in^2 or 1 bar, and the range from the threshold of hearing to potential damage to the cochlea is 0.0002-2000 μbar.

Frequency range in normal hearing: Normal persons can hear frequencies of 20 to 20000Hz but in routine audiometric tests only 125 to 8000Hz are evaluated.

Pure tone average (PTA): Frequencies of 500, 1000, and 2000Hz are called speech frequencies as most of human voice falls within this range. Pure tone average is the average threshold of hearing in dB (A) in these three frequencies. It roughly corresponds to the speech reception threshold. [3]

F. EFFECTS OF SOUND STIMULATION:

Stimulation of the ear with sound causes

1. Adaptation. (Transitory residual masking)

2. Temporary threshold shift

3. Permanent threshold shift.

Adaptation:

Adaptation or per stimulatory fatigue also known as transitory residual masking, is an immediate phenomenon which occurs when a sound is presented to the ear somewhat elevating the threshold. For fatiguing sounds of up to 90dB(A) sound pressure level (SPL) the greatest adaptation is produced for an identical test tone of an identical frequency. The spread to either side of the fatigue tone is asymmetrical with a greater effect being shown at frequencies above the fatigue frequency than below it. The amount of residual masking that remains after the fatigue tone ceases is proportional to the sound pressure level of the fatigue, but independent of its duration. The recovery is exponential in nature, and for fatiguing sounds of up to 70dB (A) SPL occurs fully within 0.5 second. There are electrophysiological correlates of this adaptation which can be measured in animals as reductions in the action potential; there appears to be significant individual variation in the amount and length of adaptation which occurs.

Temporary Threshold Shift:

This is post stimulatory fatigue or the auditory fatigue. It is divided into

- fatigue
- Long lasting temporary threshold shift- Pathological fatigue.

Fatigue:

Transition from adaptation to fatigue has been considered to result from stronger or more extended exposures. Denotes a decline in the activity resulting from previous activity of the organ. The degree of fatigue increases progressively with stimulus duration and intensity, a balance not being achieved until abnormal sound intensities are applied. Physiological fatigue lasts for more than 2 minutes but completely recovers in less than 16 hours, for this covers the situation of complete recovery after one day's work before beginning the next.

Long lasting temporary threshold shift- Pathological fatigue:

If the amount if noise exposure is sufficient, a more prolonged temporary threshold shift occurs. The cutoff point between short and long term temporary threshold shift seems to be approximately 40dB.Above this level recovery does not occur within 16 hours nor is it completely linear.

Permanent threshold shift:

There is an irreversible elevation of the auditory threshold associated with permanent pathological changes in cochlea.

G. HEARING LOSS:

Hearing loss can be of three types:

(1) **Conductive hearing loss** is caused by any disease process interfering with the conduction of sound from the external ear to stapedio-vestibular joint, Thus the cause may lie in the external ear (obstructions), tympanic membrane (perforation), middle ear (fluid), ossicles (fixation or disruption) or the Eustachian tube (obstruction).

Characteristics of conductive hearing loss:

1. Negative Rinne test, i.e. BC>AC.

2. Weber lateralized to poorer ear.

3. Normal absolute bone conduction test.

4. Low frequencies affected more.

5. Audiometry bone conduction better than air conduction with air bone gap. Greater the air bone gap more is the conductive loss.

6. Loss is not more than 60 dB.

7. Speech discrimination is good.

(2) **Sensorineural hearing loss** from lesion of the cochlea (sensory type) of VII th nerve and its central connections (neural type). The term retrocochlear is used when hearing loss is due to lesions of VIIth nerve and central deafness, when it is due to lesions of central auditory connections. It may be congenital or acquired. Acquired causes are infections of labyrinth-viral, bacterial or spirocheatal, trauma to the labyrinth or VIIth nerve, e.g. fractures of temporal bone or ear surgery, noise induced

hearing loss, ototoxic drugs, presbyacusis, meniere's disease, acoustic neuroma, sudden hearing loss, familial, systemic disorders, e.g. diabetes, hypothyroidism, kidney disease.

Characteristics of sensorineural hearing loss:

1. A positive Rinne's test, i.e. AC>BC.

2. Weber lateralized to better ear.

3. Bone conduction reduced on Schwabach and absolute bone conduction tests.

4. More often involving high frequencies.

5. No gap between air and bone conduction curve on audiometry.

6. Loss may exceed 60 dB.

7. Speech discrimination is poor.

8. There is difficulty in hearing in the presence of noise.

(3) **Mixed hearing loss**: In this type, elements of both conductive and sensorineural deafness are present in the same ear. There is air-bone gap indicating conductive element, and impairment of bone conduction indicating sensorineural loss. Mixed hearing loss is seen in some cases of otosclerosis and chronic suppurative otitis media (CSOM).[4]

H. OCCUPATIONAL NOISE INDUCED HEARING LOSS (ONIHL):

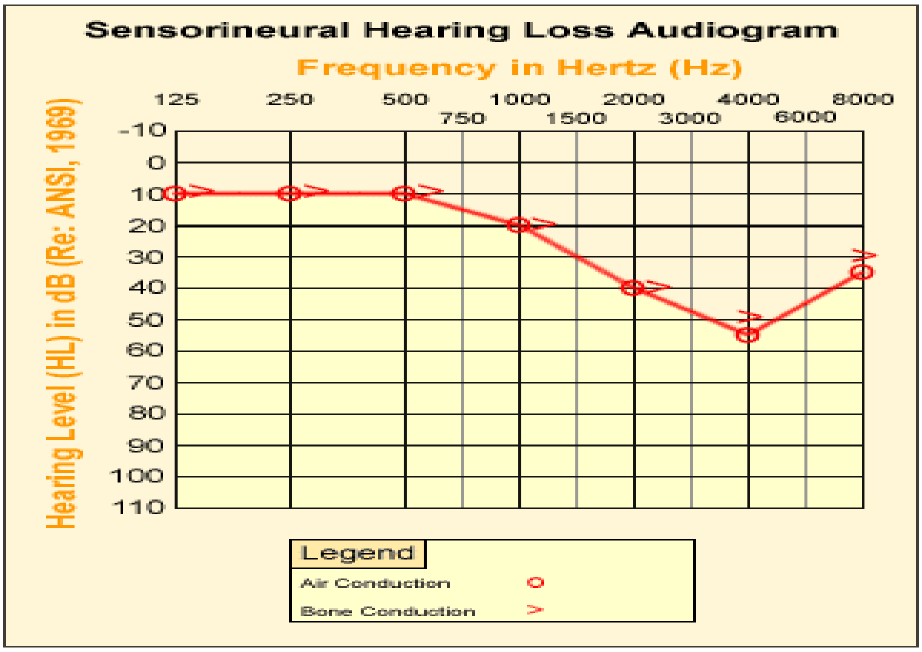
Occupational noise exposure is the most important preventable cause of hearing loss. NIHL is generally attributable to unprotected exposures above 90dB (A). It often becomes clinically apparent in middle age when age related threshold shifts are added to prior noise induced shifts. There is usually a history of recreational or occupational noise exposure, usually without hearing protection, occurring over many years. With continued noise exposure, hearing loss is progressive.

Patients with NIHL typically present with gradual, bilateral, high frequency, sensorineural hearing loss. NIHL adversely affects quality of life.

Noise can be thought of, as any sound which is unpleasant or unwanted or alternatively as a signal that delivers no information, and whose intensity varies randomly with time. For the purpose of the present study, noise is sound of sufficient intensity to damage hearing. Damage to cochlear hair cells from noise depends on the frequency, intensity and duration of exposure to noise as well as individual susceptibility. Noise may be intermittent or continuous. The interval between exposures is important, as recovery may be possible from intermittent noise. Continuous noise exposure is more damaging than interrupted exposure. The classic audiometric evidence of early noise damage is the appearance of a notch on the audiogram between 3000 and 6000Hz. The notch usually occurs at 4000Hz and then progresses to include the adjacent frequencies. It is usual for the audiogram to show recovery in both ears for frequencies above 6000Hz. If this recovery is not present, the diagnosis of NIHL should be reconsidered. It is accepted that many severe cases of NIHL do not show such a recovery sometimes this recovery is absent because of tinnitus. At first this notch is temporary (temporary threshold shift) and after rest away from noise, hearing will usually return to normal. With continuing exposure this loss becomes permanent, i.e. permanent threshold shift. Noise damage is usually similar in both ears unless one ear is more exposed to noise than the other. Where stable noise exposure continues the permanent loss at 4000 Hz will reach a maximum level after about 15years. Initial hearing loss is asymptomatic, but problems, particularly in discriminating speech in background noise will begin when loss spreads to the lower frequencies, 2000Hz or 3000Hz. At the same time as being noise exposed, when the person is ageing, and age related loss (presbyacusis) will be superimposed on the noise damage. This occurs gradually over a period of years. Highest frequencies are affected first, causing the characteristic noise induced notch to disappear from the audiogram.

Tinnitus is a subjective sensation of noise in the ears or head. There are various descriptions of tinnitus, either as a high-pitched ringing, hissing or whistling, or a low-pitched rushing or buzzing. Short periods of high-pitched whistling can be experienced before TTS or PTS is established and can be taken as a warning sign of impending hearing damage. ONIHL can occur without the person ever having noticed tinnitus.

Fig 16: Audiogram showing dip at 4000Hz.



Pathogenesis of ONIHL:

Sound damages the ear first at a frequency of about 4000Hz and one of the reasons for this is the acoustic resonance characteristics of the external ear. This hard-walled tube, closed at one end, amplifies acoustic energy in the upper frequencies by about 10 decibels. In addition, individual variation in the acoustic transfer characteristics of the tube is a factor in the large variability in people's susceptibility to noise.

Transduction of sound vibration to nerve impulses occurs in the cochlea. The hair cells in the organ of Corti may be damaged directly by noise, or indirectly by very high levels of continuous sound which causes vasoconstriction of the vessels of the stria vascular is in the cochlea blood supply. This renders the hair cells relatively anoxic and thus secondarily damaged. The amount and type of direct hair cell damage depends on the intensity of the sound. Above a certain minimum of frequency and intensity, the outer hair cells show signs of metabolic exhaustion with drooping of the stereocilia. This correlates with the common phenomenon of temporary threshold shift (TTS), which recovers within a few hours. Higher sound levels damage the outer hair cell stereocilia further, including destruction of the inter-cilial bridges, and recovery takes longer. Even higher levels of sound lead to collapse of the stereo cilia, and the hair cell are eventually phagocytosed.

Outer hair cells amplify the movement of the basilar membrane of the cochlea by contracting when stimulated by sound. This increases the stimulus delivered to the inner hair cells which transduce the mechanical movement to trigger a nervous impulse in the afferent nerve endings of the 8th nerve. If the outer hair cells are not functioning, greater stimulation is required to initiate a nervous impulse; thus the threshold sensitivity of the inner hair cells is raised which is perceived as a hearing loss. Hair cells in the basal coil of the cochlea are the most sensitive to noise damage; they are responsible for transducing higher frequencies and this accounts for the high frequency hearing loss found in noise-damaged ears.[6] NIHL is preventable. Persons who have to work at places where noise is above 90dB (A) should have pre-employment and then annual audiograms for early detection. Ear protectors (ear plugs or ear muffs) should be used where noise levels exceed 90 dB (A). They provide protection up to 35 dB.[3] Permissible exposure in cases of continuous noise or a number of short term exposures [Government of India, Ministry of Labour, Model Rules under Factories Act 1948]:

Permitted Daily sound exposure at work place.

Noise level * dB(A)	**Permitted daily exposure hours.**
90	8.0
92	6.0
95	4.0
97	3.0
100	2.0
102	1 ½
105	1.0
110	½
115	¼

- **5 dB rule** of time-intensity states that "any rise of 5 dB noise level will reduce the permitted noise exposure time to half".

The Workplace Exposure Standard is:

- Exposure of 85 dB(A) for 8hrs.
- Maximum Level 115 dB(A).
- Peak Level 140 dB (A).

I.TESTS OF HEARING

1. Tuning fork tests:

a) Rinne's test :

The Rinne test is probably the most commonly used tuning fork test. The Rinne test is a comparison of the patient's hearing sensitivity by bone conduction versus air conduction. A normal individual will perceive the air conducted sound as louder or the same as bone conducted sound. Proper placement of the tuning fork in each situation is important. When testing by bone conduction, the stem fork should be placed firmly on the mastoid, as near to the posterosuperior edge of the ear canal as possible. The stem should not touch the auricle of the external canal, which should be held to the side by the examiner's fingers. Touching the external ear itself could give false results due to vibration of the auricle. When testing by air conduction, the fork is held about 2.5 cm lateral to the tragus. In the Rinne test, when the conduction mechanism is normal in an ear (that is, in individuals with normal hearing and in those with sensorineural hearing impairment), air conduction will be heard better than bone conduction as it is a more efficient means of sound transmission. This finding is termed a positive Rinne.

Bone conduction will be heard better than air conduction when there is a deficit in the conduction mechanism and is referred to as a negative Rinne. A conductive deficit of more than 15 dB reverses the tuning fork responses (that is, bone conduction is better than air conduction) at 512 Hz.

b) Weber's test:

The Weber test is based on the principle that the signal, when transmitted by bone conduction, will be localized to the better hearing ear or the ear with the greatest conductive deficit. The test can determine the type of hearing impairment when the two ears are affected to different degrees. The stem of a vibrating tuning fork is placed on the skull in the midline, and the patient is asked to indicate in which ear the sound is heard.

The usual location described for placement is on the forehead; but better locations are the nasal bones or teeth when a stronger bone conduction stimulus is required. In unilateral hearing losses, lateralization to the poorer-hearing ear indicates an element of conductive impairment in that ear. Lateralization to the better-hearing ear suggests that the problem in the opposite ear is sensorineural. Although tuning fork tests allow the examiner to identify a conductive versus a sensorineural loss, and in some cases lateralize the symptomatic ear, it does not evaluate the degree of impairment or the effects of that impairment on speech understanding.

2**. Pure tone audiometry**

An audiometer is an electronic device which produces pure tones, the intensity of which can be increased or decreased in 5 dB steps. Air conduction Thresholds and measured for tones of 250, 500, 1000, 1500, 2000, 4000 6000 and 8000 Hz. Bone conduction thresholds and measured for 250, 500, 1000, 1500, 2000, 4000 hertz. The amount of intensity that has to be raised about the normal level is a measure of the degree of hearing impairment at that frequency. It is charted in form of a graph called the' audiogram'. The thresholds of bone conduction are a measure of the cochlear function. The difference in the thresholds of air and bone conduction (A-B gap) is a measure of a degree of conductive deafness. The audiometer is so calibrated that hearing of a normal person, both of air and bone conduction is at 0 dB and there is no A-B gap.

J. INTERPRETATION OF AN AUDIOGRAM:

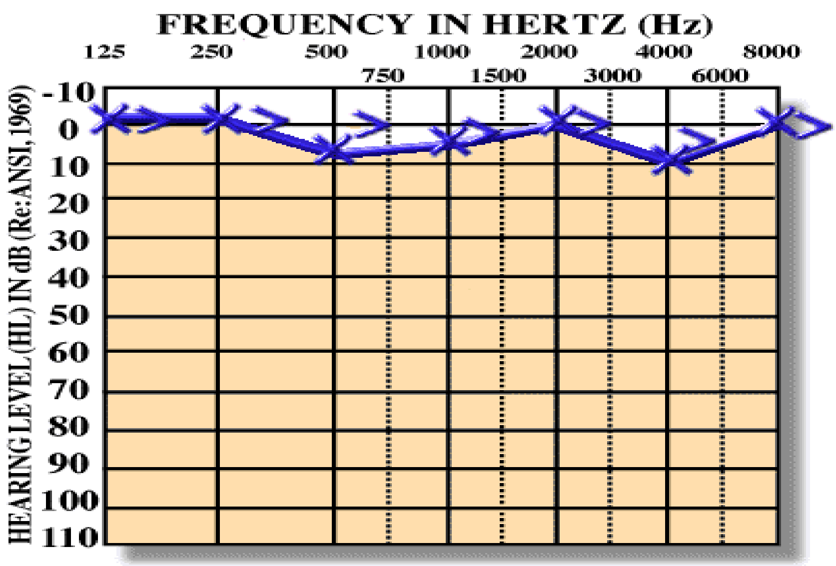
QUANTITATIVE INFORMATION:

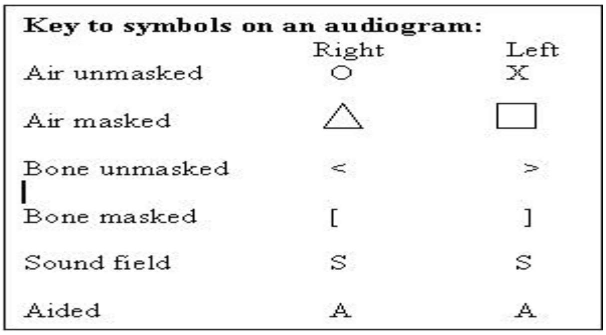
From the air conduction threshold levels the deafness can be graded into several categories like mild moderate , severe etc.

Degree of Hearing Loss [Who Classification 1980][9]

Normal	0-25 dB
Mild	26-40 dB
Moderate	41-55 dB
Severe	56-70 dB
Very Severe	71-90 dB
Profound	>90 dB

Fig 17: Normal Audiogram.





Guidelines for Audiometric Symbols (American Speech-Language-Hearing Association, 1990a)

Conductive Hearing loss- is indicated by raised air conduction thresholds (25dB) and a normal bone conduction threshold with a wide air-bone gap of 15 dB or more.

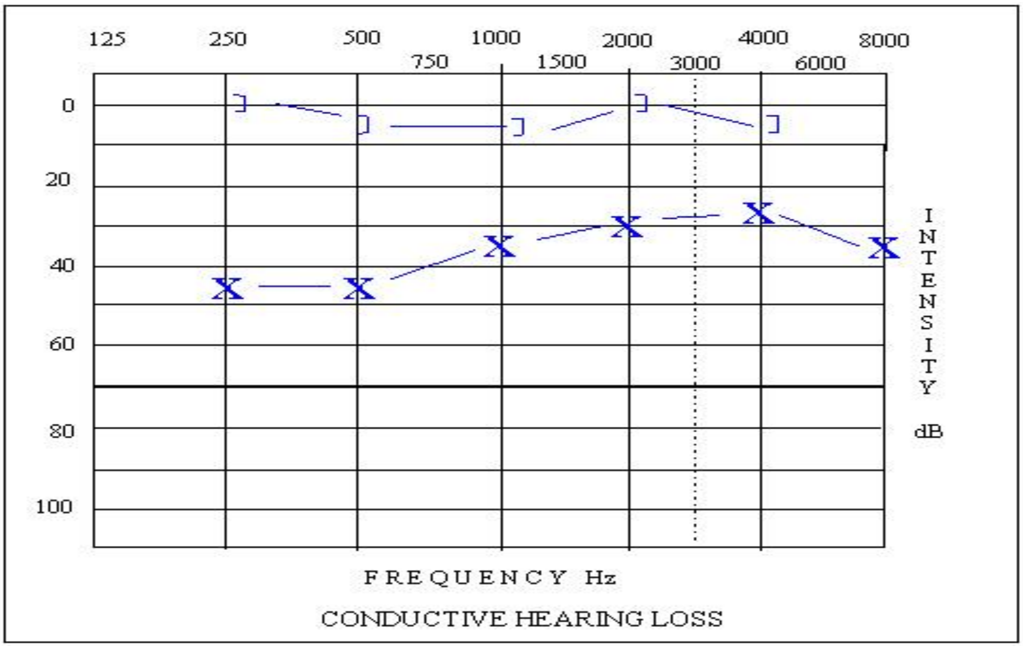


Fig 18: Audiogram Of Conductive Hearing Loss.**Sensorineural Hearing loss** -is indicated by raised air and bone conduction thresholds (both>25dB) and the air bone gap does not exceed 10dB.

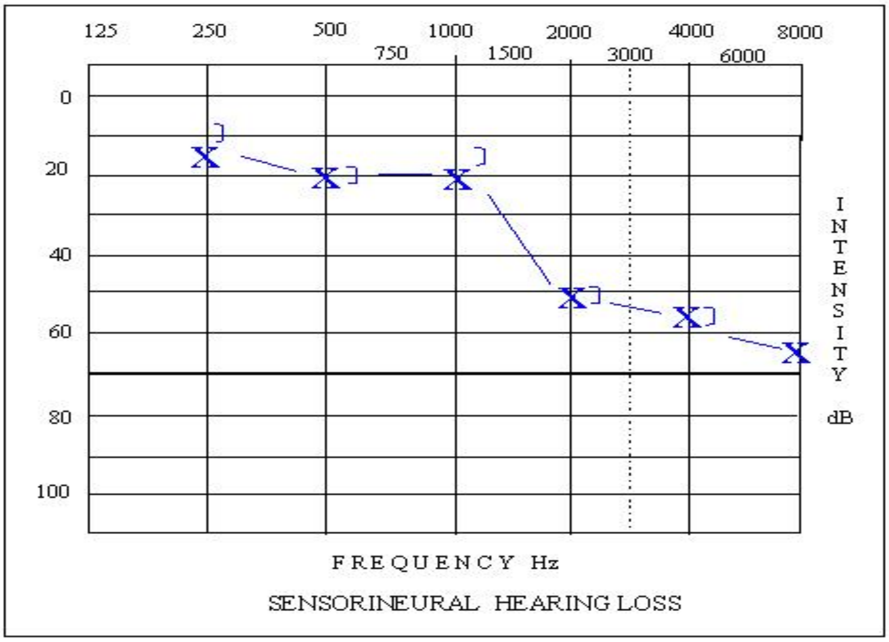


Fig 19: Audiogram of Sensorineural Hearing Loss.

Mixed Hearing loss - air and bone conduction thresholds are raised with air bone gap of > 15dB.

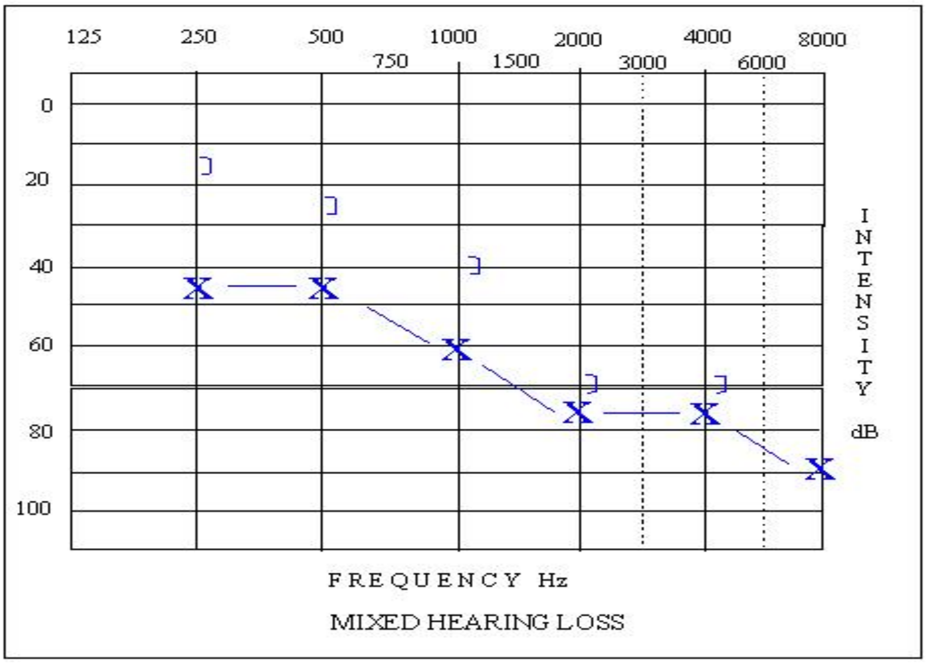


Fig 20: Audiogram of Mixed Hearing Loss.

Other tests:

Pure tone audiometry is basically a quantitative test and for qualitative information regarding the nature of pathology and the site of lesion more specialized tests like tympanometry, acoustic reflex tests, Auditory brainstem response, otoacoustic emission, speech audiometry , Acoustic reflex measures, and Static acoustic impedance.

Amongst all these tests pure tone audiometry is a simple, inexpensive, qualitative, quantitative, universal(for comparison) procedure which aims at ascertaining if the subject has an auditory disorder and also degree of hearing loss, only disadvantage being subjective.

METHODOLOGY

METHODOLOGY

MATERIALS AND METHODS:

SOURCE OF DATA:

The data was collected from workers in the granite factory and administrative staff belonging to age group >18-≤50 years after taking informed consent. Age matched exposed and non exposed groups were selected based on the following inclusion and exclusion criteria.

SAMPLE SIZE CALCULATION:

The number of subjects in each group will be calculated using the formula

$n = (Z_1)^2 - \alpha/2\ [P_1(1-P_1) + P_2(1 - P_2)] \div d^2$ where n is the number of subjects, Z_1 is the confidence interval of 95%, P_1(prevalence rate in the study group)= 0.3346 and P_2 (prevalence rate in the control group)= 0 % , d is the error of 10% (30.114- 36.806), α (intermediate value)= 0.22 for which n =85 .

The Exposed group consisted of 85 granite factory workers and unexposed group consisted of 85 workers in the administrative section.

SELECTION OF SUBJECTS:

The subjects were recruited based on inclusion and exclusion criteria from various granite factories in and around Kolar district after taking written informed consent. Ethical clearance was also obtained from Institutional Ethical Clearance Committee for the study.

CRITERIA FOR SELECTION OF SUBJECTS:

a. **Inclusion criteria**:

- **Exposed group:**

a) Male subjects aged >18 yrs to ≤50 years exposed to noise from the granite factories.

- **Non Exposed group:**

a) Male subjects aged >18 yrs to ≤50 years from the administrative section.

b. Exclusion criteria:

- **Exposed group**

a) History of consuming ototoxic drugs in past 3 months.

b) History of middle ear disease and head injuries.

c) History of hearing difficulty.

d) Use of any hearing aids.

e) Upper respiratory tract illness (common cold, Eustachian tube block)

METHODOLOGY:

Based on above predetermined inclusion and exclusion criteria, subjects were divided into Exposed and Unexposed groups.

All subjects thus selected were given a questionnaire to collect information regarding their exposure status. A general physical and systemic examination was conducted in all subjects. Also a detailed clinical ear, nose and throat examination was carried out to rule out any unidentified pathology.

The noise levels at different departments in the granite factory were recorded by using the sound level meter.

SOUND LEVEL METER



GREGORI
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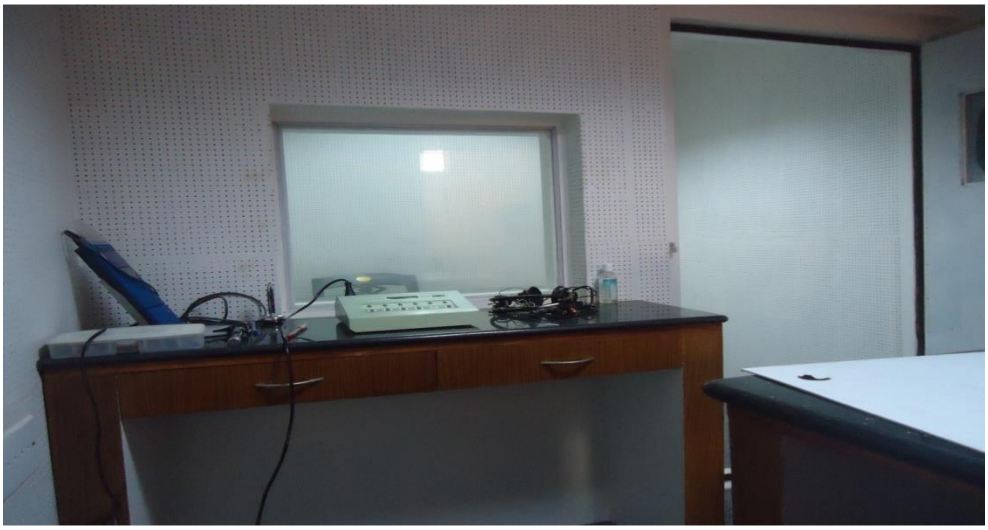
An assessment of auditory thresholds was done for different frequencies by using pure tone audiometer (ELKON-GIGA3) for both exposed and unexposed groups in a sound proof room.

SOUND PROOF ROOM:



PURE TONE AUDIOMETER:

RECORDING OF AC THRESHOLDS:

RECORDING OF BC THRESHOLDS:

PURE TONE AUDIOMETRY:

INSTRUMENT: ELKON GIGA3

PRINCIPLE:

An audiometer is an electronic device which produces pure tones, the intensity of which can be increased or decreased in 5 dB steps. Air conduction thresholds was measured for tones of 250, 500, 1000, 1500, 2000, 4000 6000 and 8000 Hz. Bone conduction thresholds was measured for 250, 500, 1000, 1500, 2000, 4000 hertz. The amount of intensity that had to be raised above the normal level was the measure of the degree of hearing impairment at that frequency. It is charted in form of a graph called the' audiogram'. The thresholds of bone conduction are a measure of the cochlear function. The difference in the thresholds of air and bone conduction (A-B gap) is a measure of a degree of conductive deafness. The audiometer is so calibrated that hearing of a normal person, both of air and bone conduction is at 0 dB and there is no A-B gap.

METHOD: [29]

The method is based on American Society for Speech and Hearing Association (ASHA) 2005 guidelines for manual pure tone threshold audiometry and is as follows.

Determination of Manual Thresholds

Before conducting threshold testing, a complete history was obtained and otoscopy was done.

Ear examination: Visual inspection of the pinna and ear canal, including otoscopy was done before audiometric testing to rule out active pathological conditions and the potential for ear canal collapse caused by audiometric earphones. The ear canal was examined for the to rule out presence of excessive cerumen before testing and the better ear was tested first.

Participant seating: The participant was made to sit in a manner to promote safety and comfort as well as valid testing. Such seating considerations were the following:

• We avoided giving inadvertent visual cues to the participant.

• Enabled easy observation of participant responses to stimuli.

• Allowed for the monitoring and reinforcement of responses.

Some of the factors that influenced the manual assessment of pure-tone thresholds are (a) the instructions to the subject, (b) the response task, and (c) the interpretation of the subject's response behavior during the test.

Instructions:

The test instructions were presented in a language or manner appropriate for the subject. Test instructions were the following:

• The purpose of the test was explained was explained to the subject, that is, to find the faintest tone that can be heard.

• Emphasized to the subject that it is necessary to sit quietly, without talking, during the test.

• The subject was also instructed to respond whenever the tone was heard, no matter how faint it was.

• The need to respond overtly as soon as the tone comes on and to respond overtly immediately when the tone goes off was described to the subject.

• Each ear was tested separately with tones of different frequencies.

Response task: The subject had to respond when he hears the tone going on and off. The response task used was pressing and releasing the signal switch.

Interpretation of response behavior: The primary parameters used in determining threshold were the presence of "on" and "off" responses, latency of responses, and number of false responses:

• Each suprathreshold presentation elicited two responses: an "on" response at the start of the test tone and an "off" response at the end of the tone. Subjects who were unable to correctly signal the termination of the tone, after proper instruction and reinstruction, were subjected to more detailed testing to diagnose the presence of any auditory problems.

• The latency of the “on” responses varies usually with the level of presentation. If the first response to a tone in an ascending series was slow, a 5-dB higher tone was presented until the response was without hesitation.

• False responses may be of two types:

(a) False positive, a response when no tone is present

(b) False negative, no response to a tone that the audiologist believes to be audible to the participant. Either type complicates the measurement procedure. Reinstruction may reduce the occurrence rate of either type.

<u>Threshold Measurement Procedure</u>

The basic procedure for threshold determination consisted of

(a) Familiarization with the test signal.

(b) Threshold measurement.

The procedure is the same regardless of frequency, output transducer, or ear under test.

a) Familiarization of the test signal:

The purpose of familiarization was done to assure that the subject understands and can perform the response task. Familiarization is a recommended practice for general populations and should be used whenever warranted by the mental or physical status of the patient. The subject was familiarized with the task before threshold determination by presenting a signal of sufficient intensity to evoke a clear response.

The following two methods of familiarization were used:

1. Beginning with a 1000Hz tone, continuously on but completely attenuated, the sound-pressure level of the tone was gradually increased until a response occurs.

2. A 1000Hz tone was presented at a 30 dB hearing level (HL). If a clear response occurred, begin threshold measurement. If no response occurred, the tone was presented at 50 dB HL and at successive additional increments of 10 dB until a response was obtained.

b) Threshold determination: an ascending technique beginning with an inaudible signal was followed in our study.

1. Pure-tone stimuli of 1 to 2 seconds' duration were given. The interval between successive tone presentations was varied but not shorter than the test tone. The level of the first presentation of the test tone was well below the expected threshold. The levels of succeeding presentations were determined by the preceding response. After each failure to respond to a signal, the level was increased in 5-dB steps until the first response occurs. After the response, the intensity was decreased 10 dB, and another ascending series was begun. (An exception is as explained previously under Interpretation of response behavior—Latency).
2. Threshold of hearing: Threshold is defined as the lowest decibel hearing level at which responses occur in at least one half of a series of ascending trials. The minimum number of responses needed to determine the threshold of hearing is two responses out of three presentations at a single level (American National Standards Institute, 2004a)

Standard Procedures for Air-Conduction Measures

Supra-aural or circumaural earphones were held in place by a headband with the earphone grid directly over the entrance to the ear canal.

Earphone placement:

The subjects were instructed to remove hats, headbands, eyeglasses, earrings, or anything that may interfere with proper positioning of the earphone cushions on the ears. After visual inspection of the outer ear, the earphones were placed on the subject and adjusted them to fit her or his head properly. Insert earphones should be placed comfortably deep in the ear canal and in accordance with manufacturer recommendations.

Stimuli:

Continuous or pulsed pure-tone signals were used. Pulsed tones have been shown to increase a test subjects' awareness of the stimuli (Burk & Wiley, 2004).

Frequency:

Threshold assessment were made at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz, except when a low-frequency hearing loss exists, in which case the hearing threshold at 125 Hz was also measured. When a difference of 20 dB or more existed between the threshold values at any two adjacent octave frequencies from 500 to 2000 Hz, interoctave measurements were made.

Order:

When appropriate information was available, the better ear was tested first. The initial test frequency was 1000Hz. Following the initial test frequency, the other frequencies , in order, 2000Hz, 3000Hz, 4000Hz, 6000Hz, and 8000Hz, followed by a retest of 1000Hz before testing 500, 250, and 125 Hz. A retest at 1000Hz is not necessary when testing the second ear. Although the order of frequencies is not likely to significantly influence test results, presentation frequencies in the order described may help ensure consistency of approach to each test participant and minimize the risk of omissions (American National Standards Institute, 2004b).

Masking for diagnostic audiometry:

Appropriate masking was applied to the non test ear when the air-conduction threshold obtained in the test ear exceeds the interaural attenuation to the non test ear. Because the procedures for masking are not confined to pure-tone measures, these procedures are not discussed in this set of guidelines.

Standard Procedures for Bone-Conduction Measures

Standard bone-conduction vibrator was placed at the mastoid with proper force applied (American National Standards Institute, 2004b; Dirks, 1964). The test ear should never be covered for standard bone conduction measurements. The contralateral ear was covered when masking was used.

The instructions during bone-conduction testing:

•The subject was asked to sit quietly and avoid movement that will dislodge the bone vibrator from the proper position.

• The subject was also asked to notify when the bone vibrator slips or moves in any way from the original placement.

Frequency: Thresholds were obtained at octave intervals from 250 to 4000Hz and at 3000Hz. Testing at frequencies below 500 Hz demands excellent sound isolation for cases with normal or near normal sensitivity but may be accomplished when such an environment is available.

Order: The initial frequency tested was 1000Hz. After the initial test frequency, the audiologist should test 2000Hz, 3000Hz, and 4000Hz followed by a retest of 1000Hz before testing 500 and 250 Hz.

Masking: If the unmasked bone-conduction threshold is 10 dB better than the air conduction threshold at that frequency in either ear, masking was used. Because the threshold values on which the calibration of bone vibrators is based were measured with masking noise in the contralateral ear, always use masking in the testing procedure.

Record Keeping

Recording of results:

Results were recorded in graphic form (audiogram).

Separate forms to represent each ear were used. The privacy and confidentiality of audiometric records must be maintained.

Audiogram form: The graphic form was used, the test frequencies were recorded on the abscissa, indicating frequency on a logarithmic scale, and hearing levels were recorded on the ordinate, using a linear scale to include the units of decibels. The aspect ratio of the audiogram is important for standardization. The correct aspect ratio is realized when a square is formed between any given octave pair on the abscissa and any 20 dB increment on the ordinate. In our study the conventional audiometry was followed, the vertical scale was designated with hearing level in decibels; the horizontal scale was labeled frequency in hertz. By convention, frequency is recorded in ascending order from left to right, and hearing level is recorded in ascending order from top to bottom, ranging from a minimum value of −10 dB to the maximum output limits of the audiometer (usually 110 or 120 dB HL).

Audiogram symbols: When the graphic form is used, the symbols presented in the Guidelines for Audiometric Symbols (American Speech-Language-Hearing Association, 1990a) should be used.

Statistical Treatment of the data: [30,31,32,33]

The data was suitably arranged into tables for discussion under different headings. Descriptive statistical analysis was carried out on this data. Results on continuous measurements are presented as mean ± standard deviation and results on categorical measurements are presented in number%. Significance was assessed at 1 % and 5% level of significance. The questionnaire data was analyzed by the chi square test. AC, BC hearing thresholds recording was compared between exposed and unexposed groups by using the student't' test. Comparison between SPL and PTA and duration of exposure and PTA was done by Anova and Post hoc Tukey's test.The Pearson correlation was done between SPL and auditory thresholds and also between duration of exposure and auditory thresholds and significance was considered based on the

RESULTS AND ANALYSIS

RESULTS:

Table 1: Comparison of age (years) of subjects in Exposed and Unexposed groups:

Age in years	**Exposed**		**Unexposed**		**p value**
	No	**%**	**No**	**%**	
< 20	13	18.82	14	18.82	0.991
20-30	29	31.76	28	35.29	
30-40	18	20.01	18	22.37	
40-50	25	29.41	25	23.52	
TOTAL	85	100	85	100	
MEAN AGE	31.12±10.56		31.11±10.59		

Samples are age matched p value 0.991

Table 1 shows the age distribution 170 subjects were selected. 13 workers in exposed and 14 workers in the unexposed groups were in the age group of < 20 yrs. 29 workers in exposed group and 28 workers in the unexposed group were in the age group of 20-30 yrs. 18 workers each in the exposed and unexposed groups respectively were between 30-40 yrs of age and 25 workers each in the exposed and unexposed groups respectively were between 40-50 yrs of age. The mean age was 31.12±10.56 yrs in the exposed group and 31.11±10.59 yrs in the unexposed group respectively. There was no statistical difference between the two groups with a P value of 0.991.

Table 2: Self-Assessed Questionnaire in the exposed and unexposed group.

Self-Assessment of hearing loss	EXPOSED (n=85)		UNEXPOSED (n=85)		X^2 value	df	p value
	Number of subjects	%	Number of subjects	%			
Quality of hearing							
• Excellent	8	9	85	10.0	140.753	3	<0.001**
• Above average	40	47	0	80.0			
• Average	28	33	0	10.0			
• Below average	9	11	0	0.0			
Hearing over phone							
• Without difficulty	48	56.0	85	100.0	47.293	1	<0.001**
• Do miss Some conversation	37	44.0	0	0.0			
Hearing in crowd							
• Without difficulty	48	56.0	85	100.0	47.293	1	<0.001**
• Do miss Some conversation	37	44.0	0	0.0			
Sound of TV/ radio							
• Usually louder	30	35.0	0	0.0	36.429	1	<0.001**
• Usually same loudness	55	65.0	85	100.0			

Do people often indicate that you are talking too loudly?							
• Yes	31	36.0	0	0.0	37.914	1	<0.001**
• No	54	64.0	85	100.0			
Tinnitus							
• More than once a day / Work related	28	33.0	0	0.0	33.521	1	<0.001**
• No tinnitus	57	67.0	85	100.0			

** Highly significant with a p value <0.01.

Table 2 shows the assessment of hearing by questionnaire method. In the present study, 44 % of the exposed population felt that their hearing ability was average or below average compared to 0% in exposed group (p value < 0.01). 44% of the exposed population had difficulty in hearing over phone and in a crowd (p value < 0.01), 35 % had to keep their TV volume loud and conversed loudly when compared to others in their families (p value < 0.01) and 32% had history of tinnitus (p value < 0.01) compared to none in the unexposed group.

Table 3: Comparison of auditory thresholds for Air Conduction (AC) in right ear among Exposed and Unexposed group:

Frequency	Auditory thresholds(dB)		p value
	Exposed	Unexposed	
250 Hz	17.24±6.10	16.76±5.96	0.612
500 Hz	19.06±6.39	18.53±6.21	0.584
1000 Hz	16.59±8.14	16.24±8.05	0.777
2000 Hz	17.29±8.71	16.88±8.63	0.757
4000Hz	21.59±10.50	12.76±6.20	<0.001**
6000 Hz	22.06±10.16	11.59±4.95	<0.001**
8000 Hz	16.47±10.11	15.53±8.31	0.508

** Highly significant with a p value <0.01.

<u>Table 4</u>: Comparison of auditory thresholds for Bone Conduction (BC) in right ear among Exposed and Unexposed group:

Frequency	Auditory thresholds(dB)		p value
	Exposed	**Unexposed**	
250 Hz	10.71±5.68	10.82±5.34	0.889
500 Hz	11.18±5.81	11.00±5.66	0.841
1000 Hz	10.94±7.09	11.29±6.82	0.741
2000 Hz	10.88±8.42	10.94±8.15	0.963
4000Hz	12.88±8.43	5.76±3.90	<0.001**

** Highly significant with a p value <0.01.

<u>Table 5</u>: Comparison of auditory thresholds for Air Conduction (AC) in left ear among Exposed and Unexposed group:

Frequency	**Auditory thresholds(dB)**		**p value**
	Exposed	**Unexposed**	
250 Hz	18.53±5.39	18.12±5.29	0.616
500 Hz	18.76±6.17	18.24±6.01	0.572
1000 Hz	18.35±8.84	17.94±8.50	0.757
2000 Hz	18.65±8.67	18.18±8.34	0.719
4000Hz	22.06±10.59	13.06±5.88	<0.001**
6000 Hz	23.59±11.33	12.29±5.43	<0.001**
8000 Hz	17.71±9.93	16.41±8.61	0.365

** Highly significant with a p value <0.01.

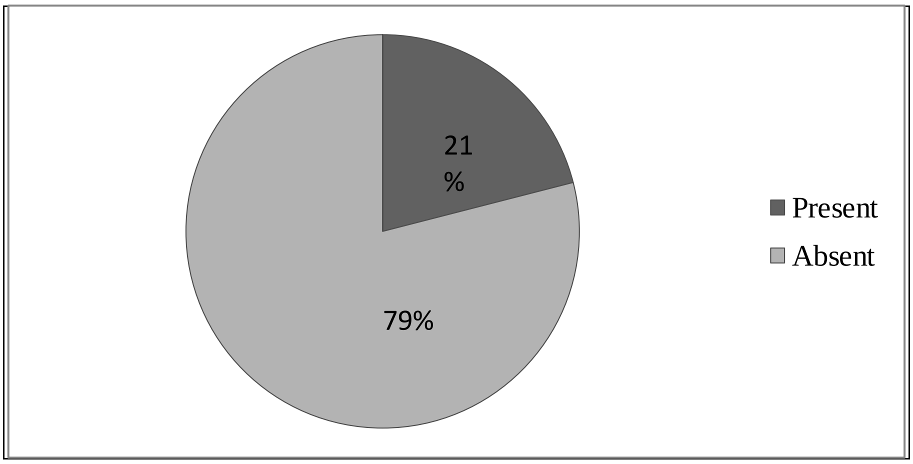
Table 6: Comparison of auditory thresholds for Bone Conduction (BC) in left ear among Exposed and Unexposed group:

Frequency	Auditory thresholds(dB)		p value
	Exposed	Unexposed	
250 Hz	10.41±5.78	10.59±5.42	0.838
500 Hz	10.53±5.62	10.41±5.19	0.887
1000 Hz	11.41±7.10	11.88±6.50	0.653
2000 Hz	10.76±8.22	10.88±7.84	0.924
4000Hz	13.59±8.58	5.88±3.95	<0.001**

** Highly significant with a p value <0.01.

Table 3,4,5,6 shows the comparison of hearing thresholds between exposed and unexposed group in both the ears. It is evident that in the exposed group, the mean thresholds at frequencies 4000 Hz (AC and BC), 6000 Hz(AC) are increased compared to that in the unexposed with the significant p value of <0.001 at frequency of 4000 Hz (AC and BC) and 6000 Hz (AC) in the left ear and also in the right ear it was statistically significant with a p value of <0.001 at 4000 Hz (AC and BC) and 6000 Hz (AC) and respectively.

Graph 1: Percentage prevalence of Hearing loss in the exposed group.



Graph 1 shows that 21 % of workers had PTA > 25dB (A) among the exposed group had pure tone average >25dB(A) and 79% of workers had normal hearing in the exposed group.

Table 7: SPL in various sections of the granite factory.

Sections Of the granite factory **Exposed group**	SPL dB(A)	Number of workers	% of workers.
Polishing	85	54	64
Cutting	95	18	21
Drilling	105	13	15
Unexposed group	65	85	100

Mean ± SD=90 ± 10 dB(A)

Table 7 shows the SPL in dB (A) recorded at different sections of the granite factory. 64 % of workers were exposed to noise of 85 dB(A) in the polishing section and 21 % of workers in the cutting section were exposed to 95 dB(A) and 15% of workers in the drilling section were exposed to 105 dB(A) compared to the unexposed workers in the administrative section who were exposed to 65 dB.The mean SPL for the exposed group is 90 $\pm$ 10 dB(A) .

Table 8: One way Anova analysis to compare the auditory thresholds of both ears in workers at different sections of the granite factory.

SECTIONS	SPL dB(A)	Auditory thresholds(dB) (Left ear)	Auditory thresholds(dB) (Right ear)
Exposed group			
Polishing	85	18.11 $\pm$6.98	17.21$\pm$7.07
Cutting	95	19.53$\pm$5.29	19.25$\pm$3.03
Drilling	105	29.61$\pm$7.93	30.25$\pm$5.84
Unexposed group	65	15.61$\pm$4.60	14.07$\pm$4.20
p value		< 0.001**	< 0.001**

** Highly significant with a p value <0.01.

Table 8 shows the comparison between SPL in dB (A) and auditory threshold (dB) in the different groups by using ANOVA and it depicts that there is significant difference in thresholds between the groups in both the ears.

A Post-hoc Tukey test was carried out for table 9 to determine which groups differ from each other and p values were obtained

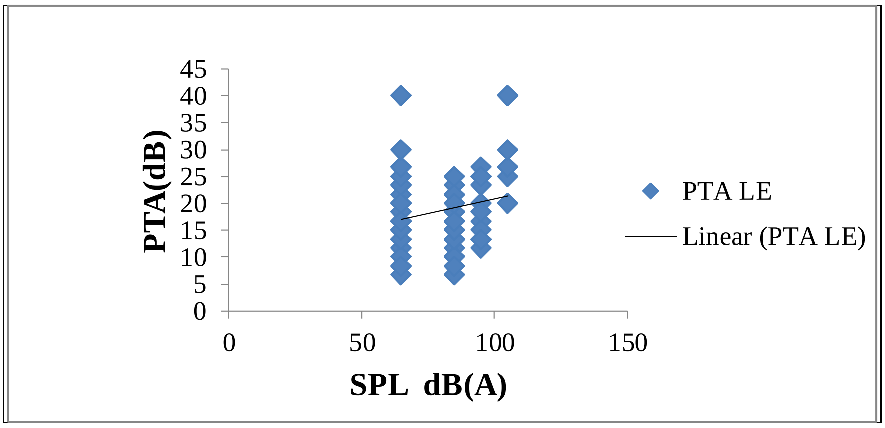
<u>Table 9:</u> Post – Hoc Tukey Analysis to compare the auditory thresholds of both ears between workers of different sections of the granite factory.

Sections	Auditory threshold (dB)	
	Left ear	Right ear
Unexposed Vs Polishers	0.101	0.013*
Unexposed Vs Cutters	0.100	0.008*
Unexposed Vs Drillers	<0.001**	<0.001**
Polishers Vs Cutters	0.817	0.537
Polishers Vs Drillers	<0.001**	<0.001**
Cutters Vs Drillers	<0.001**	<0.001**

- *Significant with a p value <0.05
- ** Highly significant with a p value <0.01

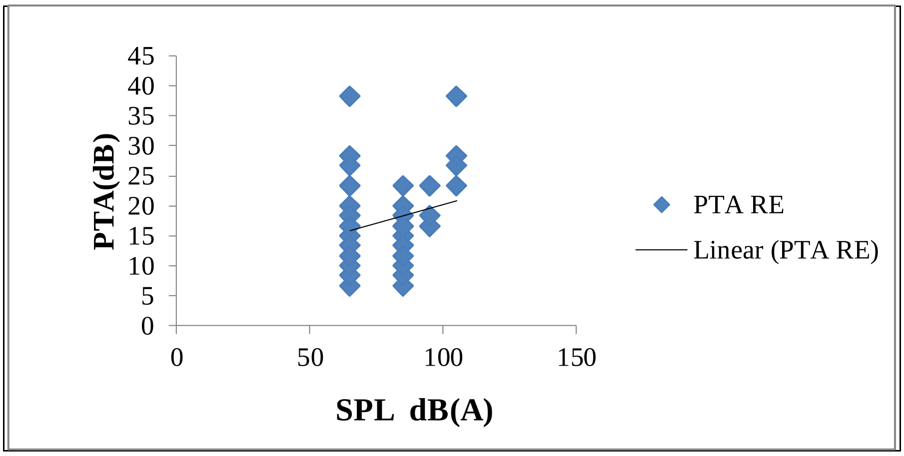
In table 9 it is depicted that there is a statistically significant difference in the auditory thresholds between the unexposed group and the Polishers, Cutters and Driller groups in the exposed population.

Graph 2: Correlation between SPL and Auditory threshold of left ear in the exposed and unexposed group.



R value- 0.226**; p value-<0.003; ** Correlation is significant at the 0.01 level (2-tailed).

Graph 3: Correlation between SPL and Auditory threshold of right ear in the exposed and unexposed group.



R value-0.250**; p value-<0.001;** Correlation is significant at the 0.01 level (2-tailed).

Graph 2&3 shows the positive correlation between the SPL and Auditory threshold (dB) in both the ears.

Table 10: Duration of exposure to noise in years within the exposed group.

Groups	No of years	No. of workers	% of workers
I	1-≤5	35	41
II	>5 - ≤10	33	39
III	>10 - ≤15	17	20
	Total	85	100.0

Mean ± SD: 7.72±4.12

Table 10 shows the distribution of workers into groups according to their duration of exposure. 41% of workers in group I had < 5 yrs of work experience,39% of workers in group II had between 5-10 yrs of work experience and 20% of workers in group III had 10-15 yrs of work experience . The mean duration of exposure was 7.72 ±4.12 yrs in the exposed group

Table 11: One way Anova analysis to compare the auditory thresholds of both ears of the groups according to the number of years of exposure.

Groups	Duration of exposure(yrs)	Auditory thresholds (dB)	
		Left ear	Right ear
I	1-<5	15.38± 4.96	13.09± 3.66
II	>5 - <10	19.04 ± 5.44	18.83± 5.59
III	>10 - <15	24.31± 10.35	24.70± 8.76
	p value	<0.001**	<0.001**

** Highly significant with a p value <0.01

In table 11 Auditory thresholds (dB) were obtained for the different groups divided according to the duration of exposure and it depicts that there is statistically significant difference in thresholds between the groups in both the ears.

A Post-hoc Tukey test was carried out for table 11 to determine which groups differ from each other and p values were obtained

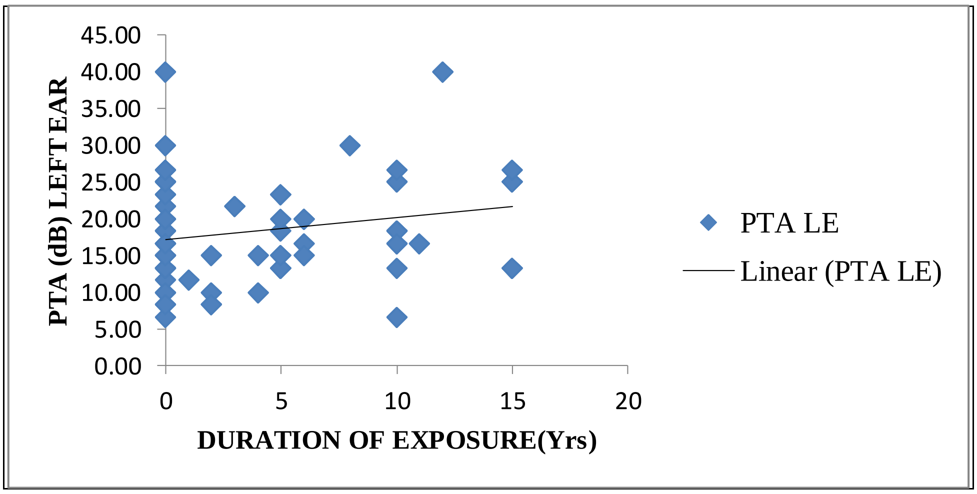
Table 12: Post Hoc Turkey analysis to compare the auditory thresholds of both ears between the groups according to the duration of exposure in the exposed group.

Groups	Auditory thresholds (dB)	
	Left ear	Right ear
I Vs II	<0.001**	0.61
II Vs III	0.003*	0.23
I Vs III	<0.001**	<0.001**

** Highly significant with a p value <0.01

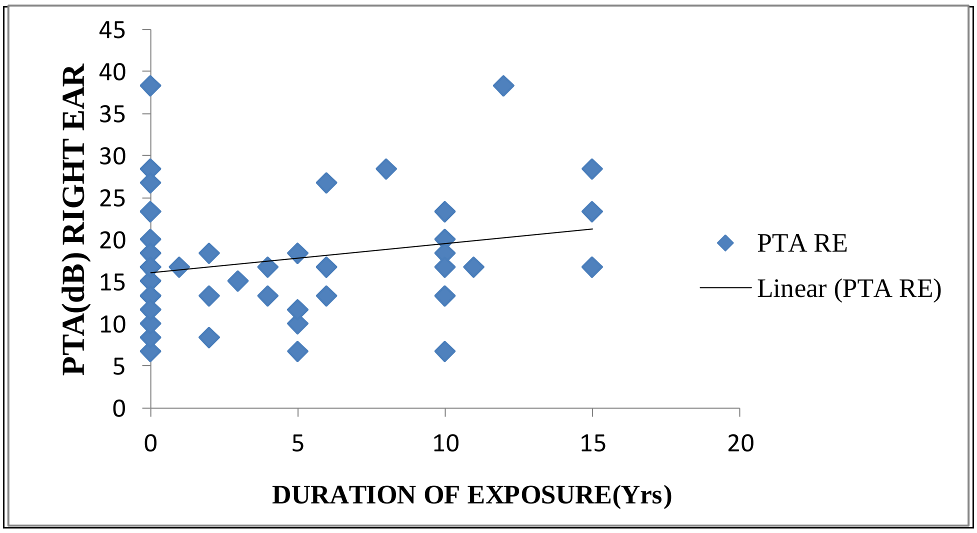
In table 12 it is depicted that there is a statistically significant difference in the auditory threshold between the group I and II , and a statistically significant difference in the auditory threshold between the group II and III, and a statistically significant difference in the auditory threshold between the group I and III.

Graph 4: Correlation between Duration of exposure and Auditory threshold of left ear in exposed group.



R value- 0.405**; P value-<0.001**; ** Correlation is significant at the 0.01 level (2-tailed).

Graph 5:.Correlation between Duration of exposure and Auditory threshold of right ear in exposed group.



R value- 0.493**; P value-<0.001**; ** Correlation is significant at the 0.01 level (2-tailed)

Graph 4&5 shows a positive correlation between duration of exposure and PTA (dB).

<u>Table 13</u>: Comparison of Exposure Index [sound pressure level in dB (A) X duration of exposure to noise in years] between the exposed and the unexposed group.

Exposure Index	**EXPOSED (n=85)**	**UNEXPOSED (n=85)**	**P value**
Mean ± SD	694.8±370.80	501.8±267.8	<0.001**

** Highly significant with a p value <0.01

Table 16 shows the comparison of exposure index which is calculated by multiplying SPL(dBA) and duration of exposure to noise(years) wherein the Mean±SD was 694.8±370.80 in exposed & 501.8± 267.8 in unexposed group and the exposure index was statistically high in test group with p<0.001**.

DISCUSSION

DISCUSSION

Chronic noise exposure is an important risk factor for NIHL. The workers engaged in the granite factories are victims of NIHL. However, data with respect to occupational health are scanty in our country. The industrial authorities as well as pollution control boards do not consider the need to prevent the hazards of noise pollution because it does not jeopardize the employee's lives immediately after exposure. However prolonged exposure which is the cause of many auditory and extra auditory effects cannot be neglected. The damaging effects on hearing depend on the level and spectrum of the noise, duration of exposure and individual susceptibility to this type of injury.[21]Relatively little data exists on the continuous noise exposure in the granite factories as a risk factor for hearing loss, although the link was established over several years ago. Hence this was an attempt to study the association between chronic noise exposure and changes in hearing thresholds in granite factory workers of Kolar.

The subjects recruited from the granite factories were in the age group of 18-50 yrs. With increasing age there is physiological alteration in hearing threshold called "presbyacusis". The effect of aging on hearing loss showed that the incidence was 1.07 times greater for each increment of one year of age, this proportion increased steeply to about 44.2% of those >75 yrs of age.[34] Therefore the mean age was 31.12+10.56 yrs in the exposed and 31.11+10.59 yrs in the unexposed group respectively in our study. There was no statistically significant difference between the two groups with a P value of 0.991and were age matched.

Quality of hearing in the granite factory workers was assessed by using a self assessed questionnaire. 11 % of the exposed group perceived their hearing to be significantly lower than the unexposed group. 44% had difficulty in hearing over phone and in a crowd, 35 % had to keep their TV volume loud and conversed loudly when compared to others in their families and 33% had history of tinnitus compared to none in the unexposed group. The first difficulty patients usually noticed was trouble understanding speech when a high level of ambient background noise was present. Impairment of hearing at high frequencies will initially cause a loss of clarity in perceived speech and then interfere with daily activities as hearing loss progresses. As ONIHL progresses, individuals may have difficulty understanding high-pitched voices (e.g., women's, children's) even in quiet conversational situations. Symptoms like difficulty in normal and telephonic conversation, turning up TV and radio volume and tinnitus occur early.[35] Difficulty in listening to conversation in these factories may be due to the fact that the noise emitted from the machines is more than 85 dBA in the human frequency range. Therefore, it is difficult to distinguish between machine noise and human noise.[36] The results of the subjective response to noise in the workers of the granite factories illustrates that there is a risk of decrease in hearing ability due to working in the predominantly noisy zone. [36] A study among traffic cops in Gujarat showed that 2.3% of the subjects felt that their hearing ability was below average.[37]A similar study done on traffic police men in our institution also revealed that the traffic police had a subjective response of difficulty in hearing and the cause being excessive noise exposure and non usage of ear plugs / ear muffs.[37] A questionnaire based study done on oil mill workers in Kharagpur ,West Bengal showed that 63% of the total workers felt that noise interfered with their conversation, 16% were of the opinion that noise interfered in their work and harmed their hearing, about 5 % stated that the work room noise gave them headaches.[36] A national telephone surveillance for prevalence of hearing loss done in Michigan reported that

29.9% of the population who had hearing loss was attributed to noise exposure at work. A large US analysis of self reported hearing impairment in industrial sectors showed that highest number of employees with hearing difficulties attributable to the occupation was found in the construction industry which includes the granite

factories .[38]

Pure tone audiometry which is a simple, inexpensive, qualitative and quantitative procedure was used to record auditory thresholds. In our study there was a statistically significant increase in air conduction thresholds at 4000 Hz and 6000 Hz in the exposed group compared to the unexposed group with a P value of <0.001 in both the ears. There was also a statistically significant increase in the bone conduction threshold at 4000 Hz in the exposed group compared to the unexposed group with a P value of <0.001in both the ears. The presence of 4000 Hz notch is a classical sign of ONIHL. The presence of 4000 Hz notch may be attributed to many factors, the human hearing is more sensitive at 100-500 Hz due to the fact that the tympanic reflex attenuates loud noise below 2000 Hz, and also due to the resonance characteristics of the external ear to loud sound, this hard walled tube, closed at one end, amplifies acoustic energy in the upper frequencies by about 10 decibels. In addition, individual variation in the acoustic transfer characteristics of the external ear is a factor in the large variability in people's susceptibility to noise. Hair cells in the basal coil of the cochlea are the most sensitive to noise damage; they are responsible for transducing higher frequencies and this accounts for the high frequency hearing loss found in ONIHL.[39,40,41]The threshold increase at 6000 Hz seen in our study was also seen among air force personnel , musicians, traffic policemen.[37,42.43] The probable cause for the 6000 Hz notch could be regular exposure to broadband frequencies of continuous noise.[42] Various studies have shown that ONIHL affected higher frequencies and mainly concentrated at 4000 Hz or 6000 Hz.[44,45]

In our study pure tone audiometry revealed that 21 % of workers in the exposed group had difficulty in hearing compared to none in the unexposed group. A cross sectional study done on workers in the LPG gas cylinder infusion factory in Taipei city, Taiwan assessed the prevalence rate by using a pure tone audiometer which revealed that 56.8% of the infield workers had NIHL.[46] Also a study done among the textile industry workers with a pure tone audiometer in Bangladesh revealed that 33.46 % of the workers had increased hearing thresholds compared to their control groups.[47]

In India, Occupational permissible exposure limit for 8 hour time weighted average is 90 dB(A).[8,48,50].Noise levels in our study was measured using a sound level meter at various sections of the granite factory .It was found that the sound pressure levels for the exposed group ranged from 85 – 120dB (A) at a distance of 1 m from the source these levels were relatively higher than the accepted limits for occupational noise exposure and also significantly higher than the sound pressure levels for the unexposed population ,which was 65dB(A). In our study the noise levels at most of the places in the granite factory was higher than 90 dB(A). It was found that the drilling section had a noise level of 105dB(A), cutting section noise level was 95dB(A), and polishing section noise level was 85dB(A).The workers in the granite factories were distributed among these sections. Various studies have shown that the noise levels were comparatively higher in the drilling section than the other sections.[50, 51]Various studies have also shown that noise levels in these granite factories were constantly high throughout the day ranging from 88.5dB – 103.5dB (A) at the factory and varying from 65-67dB(A) at the administrative section of the same factory.[51, 52] The working hours of these workers were 10-12 hrs per day. And as they dwelt in the vicinity of the same factory they were exposed to noise even when they had finished their shift work. The working schedule for the workers of the granite factories was more than 60 hours per week. The maximum stipulated hours of work by Factories Act 1948 is eight hours per day. [53] It is unfortunate that workers are still exposed to industrial noise up to 60 hours per week .Continuous exposure of the granite factory workers to these high levels of noise will accelerate their hearing impairment.[51] A 10 year review of cases of severe noise induced deafness done in Singapore revealed the 5.5 % of the cases were from the granite factories and these workers were shortlisted among those who were at high risk for noise induced hearing loss.[54] Prolonged exposure to high noise levels can lead to irreversible nerve damage ,alter the affect hormone levels and lead to psychological problems in the long run.

The auditory threshold gradually increases as the SPL increases.[8] in our study a statistically significant increase in the PTA was seen in workers of the exposed group compared to the unexposed population and the drillers had the highest auditory thresholds compared to the polishers, cutters and the unexposed groups. There was a significant positive correlation between the SPL levels and the PTA of the subjects. The plausible explanation could be that exposure to high sound levels causes TTS which recovers within 24 hrs of non exposure but repeated exposures without any break damage the outer hair cells, stereo cilia, including destruction of the interciliary bridges leading to increase recovery time. At even higher level of sound it led to a collapse of the stereocilia and the hair cells were eventually permanently damaged. If the outer hair cells were not functioning, a greater stimulation was required to initiate a nervous impulse; thus, the threshold sensitivity of inner hair cells was raised, known as the permanent threshold shift.[8] A brief interruption in noise exposure clearly resulted in significantly smaller PTS and less hair cell damage than that seen on continuous noise exposure.[55] However, the mechanism(s) by which a brief interruption in continuous noise induces the recovery process could be related to a decrease in noise-induced metabolic stress which causes reduction of blood flow, formation of reactive oxygen species, and the (Ca^{2+}) changes induced by high noise levels.[56]

Our study also showed that there was a statistically significant increase in the pure tone average as the duration of exposure increased. A positive correlation between duration of exposure and PTA was seen. The hearing loss was more at higher frequencies as compared to the lower ones and with increase in the duration of exposure this magnitude increases. A transmission electron microscopic study showed that there is edema and swelling of afferent nerve endings below the inner hair cells on exposure to noise.[57] Increased duration of exposure to high intensity sound eventually led to breakdown of organ of Corti, elimination of sensory structures and were finally got replaced by a single flat cell[58] resulting in hearing loss. The higher the intensity of sound the shorter is the duration required for the onset of hearing loss.[19]

The exposure index was calculated by duration of exposure (yrs) multiplied by the sound pressure level dB(A). The index was increased in the exposed group compared to the unexposed .The reason for the increase in exposure index is due to the high sound pressure levels the workers are exposed to in the granite factory and also the long years of exposure to noise in these workers. The amount and type of hearing loss depended on the intensity of noise and duration of exposure to noise in the workers in the exposed group during a typical working day and overall exposure during working life which had a cumulative effect on hearing.[37]

In our study we have found that the granite factory workers were exposed to sound levels as high as 105 dB which is very much above the accepted sound levels set by the factories act 1948 in these industries. The workers had an increase in auditory thresholds at 4000 Hz and 6000 Hz which is a classical sign of ONIHL. We also found that as the number of years of exposure increased their auditory thresholds also increased, initially at the higher frequencies and later progressed to the speech frequencies leading to a decline in the quality of life of these workers. We also found that, the greater the intensity of sound shorter was the duration required for the onset of hearing loss. As most of these workers belong to the unorganized sector and are in the economically productive age group, if they suffer from hearing disability at this age, they would have to live with this disability throughout their lives. Hence effective measures need to be taken at this stage. So that this health hazard could well be prevented. Thus it is suggested to implement the use of PPE's(Personal Protective Equipments) like ear plugs , ear muffs and not only should these PPEs be made available, but also periodic health checkups (audiometry) and workshops should be carried out to motivate the subjects for their correct and regular usage, and duty scheduling has to be done for exposure limitation. Ear protectors (ear plugs or ear muffs) should be used where noise levels exceed 90 dB (A). They provide protection up to 35 dB.[24] The occupational exposures to noise could be minimized by efficient control measures through engineering controls, administrative controls, and the use of personal protective devices.[59]

Preventive measures could be adopted for prevention, abatement and control of substantial amount of noise level in these industries.

SUMMARY AND CONCLUSION

SUMMARY

This study was conducted in the Department of Physiology, Sri Devaraj Urs Medical College, Kolar, to evaluate the effect of continuous noise exposure on granite factory workers. 85 granite factory workers in the exposed group and 85 administrative workers in the unexposed group were subjected to pure tone audiometer and self assessed questionnaire .11% of the granite factory workers perceived that their quality of hearing was below average according to the questionnaire. Pure tone audiometry results revealed that 21% had difficulty in hearing among the exposed group. At frequencies of 4000 Hz and 6000 Hz the exposed population had higher auditory thresholds compared to the unexposed population which is a classical sign of NIHL. The auditory thresholds of the workers engaged in various sections of the granite factory increased as the sound pressure levels in these sections were high. There was a significant positive correlation between the sound pressure levels and the auditory thresholds. The auditory thresholds also increased gradually as the duration of exposure to noise increased in these workers. There was a significant positive correlation between the duration of exposure and the auditory thresholds. The exposure index was also found to be higher as the sound pressure level these workers were exposed to be increased compared to the unexposed population. The above findings signifies that exposure to loud noise above the permitted exposure level for a prolonged period of time causes alteration in the auditory thresholds leading to hearing impairment and hearing loss.

CONCLUSIONS

1. 11 % of the granite factory workers (exposed group) perceived that they had below average quality of hearing assessed by the questionnaire.
2. Granite factory workers who were exposed to loud, continuous noise showed significantly higher thresholds in both the ears at 4000 Hz and 6000 Hz than the unexposed population.
3. Sound pressure level (dBA) was highest at the drilling section, then the cutting section and then the polishing section of the granite factory.
4. As the sound pressure levels increased the auditory thresholds of the exposed group also increased.
5. As the duration of exposure of the workers in the exposed group increased the auditory thresholds also gradually increased.

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ANNEXURES

1. CLINICAL ASSESSEMENT OF QUALITY OF HEARING

Quality of hearing Excellent, Above Average, Average, Below Average.	
Hearing over phone Without difficulty, do miss some conversation, Miss a lot of what is said.	
Hearing in crowd Without difficulty Do miss some conversation Miss a lot of what is said.	

<u>Sound of TV/radio</u> Usually louder Usually same loudness, a little louder	
<u>Do people often indicate that u r talking too loudly</u> Yes No	
<u>Do people often have to talk louder</u> Yes/no	
<u>Tinnitus</u>; almost all the time, >once a day, about a Day, about once a week, >once a year. Is it work related?	

B. i. MASTER CHART FOR SELF ASSESSMENT QUESTIONNAIRE.

	EXPOSED GROUP.						UNEXPOSED GROUP.					
Sl.no	QUALITY OF HEARING	HEARING OVER PHONE	HEARING IN THE CROWD	SOUND OF TV/RADIO	TALKING LOUDLY	H/O TINNITUS	QUALITY OF HEARING	HEARING OVER PHONE	HEARING IN THE CROWD	SOUND OF TV/RADIO	TALKING LOUDLY	H/O TINNITUS
1.	A	D	D	L	Y	N	E	WD	WD	N	N	N
2.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
3.	BA	D	D	L	Y	Y	E	WD	WD	N	N	N
4.	AA	WD	WD	N	Y	Y	E	WD	WD	N	N	N
5.	E	WD	WD	N	N	N	E	WD	WD	N	N	N
6.	A	D	D	N	N	N	E	WD	WD	N	N	N
7.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
8.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
9.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
10.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
11.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
12.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
13.	BA	D	D	L	Y	Y	E	WD	WD	N	N	N
14.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
15.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
16.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
17.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
18.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
19.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
20.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N

21.	E	WD	WD	N	N	N	E	WD	WD	N	N	N
22.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
23.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
24.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
25.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
26.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
27.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
28.	BA	D	D	L	Y	Y	E	WD	WD	N	N	N
29.	A	D	D	N	N	N	E	WD	WD	N	N	N
30.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
31.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
32.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
33.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
34.	BA	WD	WD	N	N	N	E	WD	WD	N	N	N
35.	A	D	D	L	Y	N	E	WD	WD	N	N	N
36.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
37.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
38.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
39.	E	WD	WD	N	N	N	E	WD	WD	N	N	N
40.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
41.	BA	D	D	L	Y	Y	E	WD	WD	N	N	N
42.	A	D	D	N	N	N	E	WD	WD	N	N	N
43.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
44.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
45.	E	WD	WD	N	N	N	E	WD	WD	N	N	N
46.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
47.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
48.	BA	D	D	L	Y	N	E	WD	WD	N	N	N
49.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N

50.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
51.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
52.	A	D	D	N	N	N	E	WD	WD	N	N	N
53.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
54.	BA	D	D	L	Y	Y	E	WD	WD	N	N	N
55.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
56.	E	WD	WD	N	N	N	E	WD	WD	N	N	N
57.	AA	D	D	L	Y	Y	E	WD	WD	N	N	N
58.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
59.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
60.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
61.	A	D	D	N	N	N	E	WD	WD	N	N	N
62.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
63.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
64.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
65.	A	D	D	N	N	N	E	WD	WD	N	N	N
66.	BA	D	D	L	Y	Y	E	WD	WD	N	N	N
67.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
68.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
69.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
70.	E	WD	WD	N	N	N	E	WD	WD	N	N	N
71.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
72.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
73.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
74.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
75.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
76.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
77.	BA	D	D	L	Y	Y	E	WD	WD	N	N	N
78.	E	WD	WD	N	N	N	E	WD	WD	N	N	N

79.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
80.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
81.	A	D	D	N	N	N	E	WD	WD	N	N	N
82.	A	D	D	L	Y	Y	E	WD	WD	N	N	N
83.	E	WD	WD	N	N	N	E	WD	WD	N	N	N
84.	AA	WD	WD	N	N	N	E	WD	WD	N	N	N
85.	A	D	D	L	Y	Y	E	WD	WD	N	N	N

ii.MASTER CHART –AUDITORY THRESHOLDS (dB) OF RIGHT EAR IN EXPOSED GROUP.

SL NO	AGE	EXP YEARS	250Hz		500Hz		1000Hz		2000Hz		4000Hz		6000Hz		8000Hz		
			AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	PTA
1	24	3	20	15	20	20	15	10	10	5	10	5	15	*	15	*	14
2	22	2	5	0	5	5	10	0	10	0	10	0	10	*	10	*	9
3	24	5	15	10	10	10	10	5	10	5	10	5	10	*	5	*	10
4	29	10	20	0	25	0	20	0	15	0	10	5	15	*	5	*	18
5	35	15	20	15	20	15	25	20	25	20	30	20	35	*	25	*	25
6	36	12	30	20	30	20	40	25	45	35	40	30	40	*	45	*	39
7	35	5	15	15	15	15	20	15	20	15	40	25	25	*	25	*	24
8	30	10	25	15	25	15	20	15	25	15	25	20	35	*	15	*	24
9	29	15	15	5	20	5	15	10	15	5	30	10	30	*	15	*	20
10	30	10	20	20	20	20	15	15	20	20	25	15	20	*	15	*	20
11	28	5	10	5	10	5	10	10	15	5	25	10	25	*	15	*	15
12	32	10	15	10	20	10	15	10	15	10	15	10	15	*	10	*	16
13	20	6	25	10	30	10	25	15	25	15	40	20	35	*	35	*	30
14	29	11	20	15	20	10	15	15	15	15	15	15	15	*	10	*	16
15	21	4	15	10	15	5	15	10	20	10	20	10	25	*	10	*	18
16	20	1	20	15	25	15	15	5	10	10	20	5	20	*	15	*	18
17	28	10	15	5	15	5	15	10	10	5	15	10	15	*	15	*	14
18	22	2	10	10	15	10	10	0	15	0	20	5	15	*	10	*	15
19	21	5	10	10	15	5	0	0	5	5	15	5	10	*	10	*	9
20	22	4	15	10	20	10	10	5	10	5	15	10	15	*	10	*	14
21	28	6	10	5	20	15	15	15	15	15	20	20	20	*	5	*	18
22	24	10	10	5	10	5	5	5	5	0	5	0	5	*	5	*	6
23	24	3	20	15	20	20	15	10	10	5	10	5	15	*	15	*	14
24	22	2	5	0	5	5	10	0	10	0	10	0	10	*	10	*	9
25	24	5	15	10	10	10	10	5	10	5	10	5	10	*	5	*	10
26	29	10	20	0	25	0	20	0	15	0	10	5	15	*	5	*	18
27	35	15	20	15	20	15	25	20	25	20	30	20	35	*	25	*	25
28	36	12	30	20	30	20	40	25	45	35	40	30	40	*	45	*	39
29	35	5	15	15	15	15	20	15	20	15	40	25	25	*	25	*	24
30	30	10	25	15	25	15	20	15	25	15	25	30	35	*	15	*	24
31	29	15	15	5	20	5	15	10	15	5	30	10	30	*	15	*	20
32	28	5	15	10	20	10	5	5	10	10	15	10	15	*	15	*	13

33	32	10	20	10	25	10	20	15	25	15	45	25	35	*	20	*	29
34	28	5	15	5	15	5	10	10	10	10	15	15	15	*	20	*	13
35	30	2	20	15	20	15	15	10	20	15	20	15	20	*	15	*	19
36	37	15	30	15	30	15	30	25	25	15	25	15	45	*	35	*	28
37	35	6	15	15	20	20	15	15	15	15	15	10	25	*	15	*	16
38	32	8	25	20	25	20	30	25	30	25	25	25	30	*	30	*	28
39	26	6	10	10	15	10	15	10	10	5	15	5	10	*	5	*	14
40	34	10	15	10	15	10	10	5	15	10	15	10	15	*	15	*	14
41	24	3	20	15	20	20	15	10	10	5	10	5	15	*	15	*	14
42	22	2	5	0	5	5	10	0	10	0	10	0	10	*	10	*	9
43	24	5	15	10	10	10	10	5	10	5	10	5	10	*	5	*	10
44	29	10	20	0	25	0	20	0	15	0	10	5	15	*	5	*	18
45	35	15	20	15	20	15	25	20	25	20	30	20	35	*	25	*	25
46	36	12	30	20	30	20	40	25	45	35	40	30	40	*	45	*	39
47	35	5	15	15	15	15	20	15	20	15	40	25	25	*	25	*	24
48	30	10	25	15	25	15	20	15	25	15	25	20	35	*	15	*	24
49	29	15	15	5	20	5	15	10	15	5	30	10	30	*	15	*	20
50	30	10	20	20	20	20	15	15	20	20	25	15	20	*	15	*	20
51	28	5	10	5	10	5	10	10	15	5	25	10	25	*	15	*	15
52	32	10	15	10	20	10	15	10	15	10	15	10	15	*	10	*	16
53	20	6	25	10	30	10	25	15	25	15	40	20	35	*	35	*	30
54	29	11	20	15	20	10	15	15	15	15	15	15	15	*	10	*	16
55	21	4	15	10	15	5	15	10	20	10	20	10	25	*	10	*	18
56	20	1	20	15	25	15	15	5	10	10	20	5	20	*	15	*	18
57	28	10	15	5	15	5	15	10	10	5	15	10	15	*	15	*	14
58	22	2	10	10	15	10	10	0	15	0	20	5	15	*	10	*	15
59	21	5	10	10	15	5	0	0	5	5	15	5	10	*	10	*	9
60	22	4	15	10	20	10	10	5	10	5	15	10	15	*	10	*	14
61	28	6	10	5	20	15	15	15	15	15	20	20	20	*	5	*	18
62	24	10	10	5	10	5	5	5	5	0	5	0	5	*	5	*	6
63	24	3	20	15	20	20	15	10	10	5	10	5	15	*	15	*	14
64	22	2	5	0	5	5	10	0	10	0	10	0	10	*	10	*	9
65	24	5	15	10	10	10	10	5	10	5	10	5	10	*	5	*	10
66	29	10	20	0	25	0	20	0	15	0	10	5	15	*	5	*	18
67	35	15	20	15	20	15	25	20	25	20	30	20	35	*	25	*	25
68	36	12	30	20	30	20	40	25	45	35	40	30	40	*	45	*	39

69	35	5	15	15	15	15	20	15	20	15	40	25	25	*	25	*	24
70	30	10	25	15	25	15	20	15	25	15	25	30	35	*	15	*	24
71	29	15	15	5	20	5	15	10	15	5	30	10	30	*	15	*	20
72	28	5	15	10	20	10	5	5	10	10	15	10	15	*	15	*	13
73	32	10	20	10	25	10	20	15	25	15	45	25	35	*	20	*	29
74	28	5	15	5	15	5	10	10	10	10	15	15	15	*	20	*	13
75	30	2	20	15	20	15	15	10	20	15	20	15	20	*	15	*	19
76	37	15	30	15	30	15	30	25	25	15	25	15	45	*	35	*	28
77	35	6	15	15	20	20	15	15	15	15	15	10	25	*	15	*	16
78	32	8	25	20	25	20	30	25	30	25	25	25	30	*	30	*	28
79	26	6	10	10	15	10	15	10	10	5	15	5	10	*	5	*	14
80	34	10	15	10	15	10	10	5	15	10	15	10	15	*	15	*	14
81	29	15	15	5	20	5	15	10	15	5	30	10	30	*	15	*	20
82	30	10	20	20	20	20	15	15	20	20	25	15	20	*	15	*	20
83	28	5	10	5	10	5	10	10	15	5	25	10	25	*	15	*	15
84	32	10	15	10	20	10	15	10	15	10	15	10	15	*	10	*	16
85	20	6	25	10	30	10	25	15	25	15	40	20	35	*	35	*	30

iii.MASTER CHART –AUDITORY THRESHOLDS (dB) OF LEFT EAR IN EXPOSED GROUP.

SL NO	AGE	EXP YEARS	250Hz		500Hz		1000Hz		2000Hz		4000Hz		6000Hz		8000Hz		
			AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	PTA
1	24	3	25	15	30	20	20	10	15	5	15	5	15	*	20	*	20
2	22	2	10	0	5	5	10	0	10	0	5	0	5	*	5	*	8
3	24	5	15	10	15	10	10	5	15	5	15	5	15	*	15	*	14
4	29	10	20	0	20	0	20	0	15	0	20	5	15	*	5	*	19
5	35	15	25	15	25	15	25	20	25	20	30	20	30	*	30	*	26
6	36	12	30	20	30	20	45	25	45	35	45	30	45	*	40	*	41
7	35	5	15	15	20	15	25	15	25	15	40	25	30	*	25	*	28
8	30	10	25	15	25	15	25	15	25	15	30	20	35	*	20	*	26
9	29	15	15	5	15	5	10	10	15	5	15	10	30	*	10	*	14
10	30	10	20	20	20	20	15	15	20	15	20	15	40	*	30	*	19
11	28	5	15	5	15	5	10	10	20	5	15	10	20	*	10	*	15
12	32	10	15	15	20	15	10	10	20	15	15	10	15	*	10	*	16
13	20	6	20	10	15	10	25	15	20	15	30	20	30	*	25	*	23
14	29	11	20	5	20	5	15	15	15	15	15	15	15	*	10	*	16
15	21	4	20	10	15	5	15	10	15	10	20	10	15	*	5	*	16
16	20	1	15	15	15	15	10	5	10	10	15	5	15	*	10	*	13
17	28	10	10	5	15	5	15	10	10	5	20	10	20	*	20	*	15
18	22	2	10	10	10	10	10	0	10	0	20	5	15	*	15	*	13
19	21	5	10	10	15	5	25	0	15	5	15	5	15	*	10	*	18
20	22	4	10	10	10	10	10	5	10	5	20	10	20	*	25	*	13
21	28	6	15	5	20	15	20	20	20	20	25	25	20	*	15	*	21
22	24	10	15	5	10	5	5	5	5	0	5	0	5	*	0	*	6
23	24	3	25	15	30	20	20	10	15	5	15	5	5	*	20	*	20
24	22	2	10	0	5	5	10	0	10	0	5	0	15	*	5	*	8
25	24	5	15	10	15	10	10	5	15	5	15	5	5	*	15	*	14
26	29	10	20	0	20	0	20	0	15	0	20	5	15	*	5	*	19
27	35	15	25	15	25	15	25	20	25	20	30	20	30	*	30	*	26
28	36	12	30	20	30	20	45	25	45	35	45	30	45	*	40	*	41
29	35	5	15	15	20	15	25	15	25	15	40	25	30	*	25	*	28

30	30	10	25	15	25	15	25	15	25	15	30	20	35	*	20	*	26
31	29	15	15	5	15	5	10	10	15	5	15	10	30	*	10	*	14
32	28	5	20	5	20	5	15	10	25	5	30	20	35	*	30	*	23
33	32	10	25	10	25	10	25	10	30	15	45	25	30	*	20	*	31
34	28	5	20	5	15	5	15	15	10	10	15	10	20	*	15	*	14
35	30	2	20	15	15	10	20	15	10	10	15	10	25	*	25	*	15
36	37	15	20	10	25	15	30	25	25	15	35	25	50	*	30	*	29
37	35	6	20	20	20	10	15	10	15	10	15	15	20	*	15	*	16
38	32	8	25	10	25	10	30	25	35	20	35	30	40	*	30	*	31
39	26	6	20	10	20	10	15	10	10	10	15	15	20	*	5	*	15
40	34	10	20	15	20	10	15	15	15	15	20	15	20	*	15	*	18
41	24	3	25	15	30	20	20	10	15	5	15	5	15	*	20	*	20
42	22	2	10	0	5	5	10	0	10	0	5	0	5	*	5	*	8
43	24	5	15	10	15	10	10	5	15	5	15	5	15	*	15	*	14
44	29	10	20	0	20	0	20	0	15	0	20	5	15	*	5	*	19
45	35	15	25	15	25	15	25	20	25	20	30	20	30	*	30	*	26
46	36	12	30	20	30	20	45	25	45	35	45	30	45	*	40	*	41
47	35	5	15	15	20	15	25	15	25	15	40	25	30	*	25	*	28
48	30	10	25	15	25	15	25	15	25	15	30	20	35	*	20	*	26
49	29	15	15	5	15	5	10	10	15	5	15	10	30	*	10	*	14
50	30	10	20	20	20	20	15	15	20	15	20	15	40	*	30	*	19
51	28	5	15	5	15	5	10	10	20	5	15	10	20	*	10	*	15
52	32	10	15	15	20	15	10	10	20	15	15	10	15	*	10	*	16
53	20	6	20	10	15	10	25	15	20	15	30	20	30	*	25	*	23
54	29	11	20	5	20	5	15	15	15	15	15	15	15	*	10	*	16
55	21	4	20	10	15	5	15	10	15	10	20	10	15	*	5	*	16
56	20	1	15	15	15	15	10	5	10	10	15	5	15	*	10	*	13
57	28	10	10	5	15	5	15	10	10	5	20	10	20	*	20	*	15
58	22	2	10	10	10	10	10	0	10	0	20	5	15	*	15	*	13
59	21	5	10	10	15	5	25	0	15	5	15	5	15	*	10	*	18
60	22	4	10	10	10	10	10	5	10	5	20	10	20	*	25	*	13
61	28	6	15	5	20	15	20	20	20	20	25	25	20	*	15	*	21
62	24	10	15	5	10	5	5	5	5	0	5	0	5	*	0	*	6
63	24	3	25	15	30	20	20	10	15	5	15	5	5	*	20	*	20
64	22	2	10	0	5	5	10	0	10	0	5	0	15	*	5	*	8
65	24	5	15	10	15	10	10	5	15	5	15	5	5	*	15	*	14

66	29	10	20	0	20	0	20	0	15	0	20	5	15	*	5	*	19
67	35	15	25	15	25	15	25	20	25	20	30	20	30	*	30	*	26
68	36	12	30	20	30	20	45	25	45	35	45	30	45	*	40	*	41
69	35	5	15	15	20	15	25	15	25	15	40	25	30	*	25	*	28
70	30	10	25	15	25	15	25	15	25	15	30	20	35	*	20	*	26
71	29	15	15	5	15	5	10	10	15	5	15	10	30	*	10	*	14
72	28	5	20	5	20	5	15	10	25	5	30	20	35	*	30	*	23
73	32	10	25	10	25	10	25	10	30	15	45	25	30	*	20	*	31
74	28	5	20	5	15	5	15	15	10	10	15	10	20	*	15	*	14
75	30	2	20	15	15	10	20	15	10	10	15	10	25	*	25	*	15
76	37	15	20	10	25	15	30	25	25	15	35	25	50	*	30	*	29
77	35	6	20	20	20	10	15	10	15	10	15	15	20	*	15	*	16
78	32	8	25	10	25	10	30	25	35	20	35	30	40	*	30	*	31
79	26	6	20	10	20	10	15	10	10	10	15	15	20	*	5	*	15
80	34	10	20	15	20	10	15	15	15	15	20	15	20	*	15	*	18
81	29	15	15	5	15	5	10	10	15	5	15	10	30	*	10	*	14
82	30	10	20	20	20	20	15	15	20	15	20	15	40	*	30	*	19
83	28	5	15	5	15	5	10	10	20	5	15	10	20	*	10	*	15
84	32	10	15	15	20	15	10	10	20	15	15	10	15	*	10	*	16
85	20	6	20	10	15	10	25	15	20	15	30	20	30	*	25	*	23

iv.MASTER CHART –AUDITORY THRESHOLDS(dB) OF RIGHT EAR IN UNEXPOSED GROUP.

SL NO	AGE	250Hz		500Hz		1000Hz		2000Hz		4000Hz		6000Hz		8000Hz		
		AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	PTA
1	27	20	15	20	20	15	10	10	5	5	5	10	*	15	*	8
2	27	5	10	5	5	10	10	10	10	10	5	10	*	10	*	9
3	32	15	10	10	10	10	5	10	5	20	5	15	*	5	*	14
4	36	15	15	20	0	15	15	10	10	15	5	15	*	5	*	16
5	29	20	15	20	15	25	20	25	20	15	5	15	*	20	*	18
6	21	30	20	30	20	40	25	45	35	20	10	15	*	35	*	18
7	30	15	15	15	15	20	15	20	15	20	10	15	*	25	*	16
8	32	25	15	25	15	20	15	25	15	15	5	10	*	15	*	14
9	21	15	5	20	5	15	10	15	5	20	5	20	*	15	*	16
10	26	20	20	20	20	15	15	20	20	20	10	20	*	15	*	16
11	23	10	5	10	5	10	10	15	5	10	5	10	*	15	*	11
12	21	15	10	20	10	15	10	15	10	5	0	5	*	10	*	6
13	22	20	10	20	10	20	15	20	15	5	0	5	*	35	*	13
14	21	20	15	20	10	15	15	15	15	5	0	5	*	10	*	9
15	23	15	10	15	5	15	10	20	10	5	0	5	*	10	*	10
16	27	15	10	20	10	10	15	10	10	5	5	5	*	15	*	9
17	39	15	5	15	5	15	10	10	5	10	5	5	*	15	*	9
18	35	10	10	15	10	10	0	15	0	20	10	15	*	10	*	13
19	24	10	10	15	5	0	0	5	5	10	5	10	*	10	*	14
20	40	15	10	20	10	10	5	10	5	20	15	15	*	10	*	13
21	26	10	5	20	15	15	15	15	15	10	10	15	*	5	*	10
22	27	10	5	10	5	5	5	5	0	10	5	10	*	5	*	9
23	27	20	15	20	20	15	10	10	5	5	5	10	*	15	*	8
24	27	5	0	5	5	10	0	10	0	10	5	10	*	10	*	9
25	32	15	10	10	10	10	5	10	5	20	5	15	*	5	*	14
26	36	20	0	25	0	20	0	15	0	15	5	15	*	5	*	16
27	29	15	15	15	15	15	15	15	10	15	5	15	*	20	*	18
28	21	30	20	30	20	40	25	45	35	20	10	15	*	35	*	18
29	30	15	15	15	15	20	15	20	15	20	10	15	*	25	*	16
30	32	25	15	25	15	20	15	25	15	15	5	10	*	15	*	14
31	21	15	5	20	5	15	10	15	5	20	5	20	*	15	*	16

32	27	15	10	20	10	5	5	10	10	15	5	5	*	15	*	14
33	35	20	10	25	10	20	15	25	15	20	15	20	*	20	*	15
34	21	15	5	15	5	10	10	10	10	5	5	10	*	20	*	9
35	26	20	15	20	15	15	10	20	15	10	10	15	*	15	*	14
36	21	30	15	30	15	30	25	25	15	20	10	15	*	35	*	18
37	30	15	15	20	20	15	15	15	15	20	10	15	*	15	*	16
38	22	25	20	25	20	30	25	30	25	5	0	5	*	20	*	13
39	21	10	10	15	10	15	10	10	5	5	0	5	*	5	*	9
40	27	15	10	15	10	10	5	15	10	5	5	10	*	15	*	8
41	27	20	15	20	20	15	10	10	5	10	5	10	*	15	*	9
42	32	5	0	5	5	10	0	10	0	20	5	15	*	10	*	14
43	36	15	10	10	10	10	5	10	5	15	5	15	*	5	*	16
44	29	20	0	25	0	20	0	15	0	15	5	15	*	5	*	18
45	21	20	15	20	15	25	20	25	20	20	10	15	*	25	*	18
46	30	30	20	30	20	40	25	45	35	20	10	15	*	35	*	16
47	32	15	15	15	15	20	15	20	15	15	5	10	*	25	*	14
48	21	25	15	25	15	20	15	25	15	20	5	20	*	15	*	16
49	26	15	5	20	5	15	10	15	5	20	10	20	*	15	*	16
50	23	15	15	15	15	15	15	15	15	10	5	10	*	15	*	11
51	21	10	5	10	5	10	10	15	5	5	0	5	*	15	*	6
52	22	15	10	20	10	15	10	15	10	5	0	5	*	10	*	13
53	21	25	10	30	10	25	15	25	15	5	0	5	*	30	*	9
54	23	20	15	20	10	15	15	15	15	5	0	5	*	10	*	10
55	27	15	10	15	5	15	10	20	10	5	5	5	*	10	*	9
56	39	20	15	25	15	15	5	10	10	10	5	5	*	15	*	9
57	35	15	5	15	5	15	10	10	5	20	10	15	*	15	*	13
58	24	10	10	15	10	10	0	15	0	10	5	10	*	10	*	14
59	40	10	10	15	5	0	0	5	5	20	15	15	*	10	*	13
60	26	15	10	20	10	10	5	10	5	10	10	15	*	10	*	10
61	27	10	5	20	15	15	15	15	15	10	5	10	*	5	*	9
62	27	10	5	10	5	5	5	5	0	5	5	10	*	5	*	8
63	27	15	10	15	15	15	10	10	5	10	5	10	*	15	*	9
64	32	5	0	5	5	10	0	10	0	20	5	15	*	10	*	14
65	36	15	10	10	10	10	5	10	5	15	5	15	*	5	*	16
66	29	20	0	25	0	20	0	15	0	15	5	15	*	5	*	18
67	21	20	15	20	15	25	20	25	20	20	10	15	*	25	*	18

68	30	30	20	30	20	40	25	45	35	20	10	15	*	30	*	16
69	32	15	15	15	15	20	15	20	15	15	5	10	*	20	*	14
70	21	15	15	15	15	15	15	15	15	20	5	20	*	15	*	16
71	27	15	5	20	5	15	10	15	5	15	5	5	*	15	*	14
72	35	15	10	20	10	5	5	10	10	20	15	20	*	15	*	15
73	21	20	10	25	10	20	15	25	15	5	5	10	*	20	*	9
74	26	15	5	15	5	10	10	10	10	10	10	15	*	20	*	14
75	21	20	15	20	15	15	10	20	15	20	10	15	*	15	*	18
76	30	30	15	30	15	30	25	25	15	20	10	15	*	35	*	16
77	22	15	15	20	20	15	15	15	15	5	0	5	*	15	*	13
78	21	25	20	25	20	30	25	30	25	5	0	5	*	30	*	9
79	26	10	10	15	10	15	10	10	5	20	10	20	*	5	*	16
80	23	15	10	15	10	10	5	15	10	10	5	10	*	15	*	11
81	21	15	5	20	5	15	10	15	5	5	0	5	*	15	*	6
82	22	20	20	20	20	15	15	20	20	5	0	5	*	15	*	13
83	21	10	5	10	5	10	10	15	5	5	0	5	*	15	*	9
84	23	15	10	20	10	15	10	15	10	5	0	5	*	10	*	10
85	27	25	10	30	10	25	15	25	15	5	5	5	*	30	*	9

v.MASTER CHART –AUDITORY THRESHOLDS(dB) OF LEFT EAR IN UNEXPOSED GROUP.

SL NO	AGE	250Hz		500Hz		1000Hz		2000Hz		4000Hz		6000Hz		8000Hz		
		AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	PTA
1	27	25	15	30	20	20	10	15	5	5	5	5	*	15	*	5
2	27	10	20	5	5	10	20	10	10	15	5	10	*	5	*	11
3	32	15	10	15	10	10	5	15	5	15	5	15	*	15	*	14
4	36	20	20	20	20	20	20	15	20	15	5	15	*	5	*	18
5	29	25	15	25	15	25	20	25	20	15	5	15	*	20	*	15
6	21	30	20	30	20	45	25	45	35	20	10	20	*	30	*	18
7	30	15	15	20	15	25	15	25	15	20	10	15	*	20	*	18
8	32	25	15	25	15	25	15	25	15	20	5	15	*	15	*	18
9	21	15	5	15	5	10	10	15	5	20	5	20	*	10	*	16
10	26	10	10	10	10	10	10	10	10	20	10	15	*	25	*	16
11	23	15	5	15	5	10	10	20	5	10	5	10	*	10	*	9
12	21	15	15	20	15	10	10	20	15	5	0	5	*	10	*	8
13	22	20	10	15	10	25	15	20	15	5	0	5	*	20	*	13
14	21	20	5	20	5	15	15	15	15	5	0	5	*	10	*	9
15	23	20	10	15	5	15	10	15	10	5	0	5	*	5	*	10
16	27	15	15	15	15	10	5	10	10	10	5	5	*	10	*	9
17	39	10	5	15	5	15	10	10	5	5	5	5	*	15	*	6
18	35	10	10	10	10	10	0	10	0	10	5	10	*	15	*	11
19	24	10	10	15	5	25	0	15	5	15	5	10	*	10	*	13
20	40	10	10	10	10	10	5	10	5	20	15	15	*	20	*	14
21	26	15	5	20	15	20	20	20	20	10	10	15	*	15	*	9
22	27	15	5	10	5	5	5	5	0	15	5	10	*	0	*	9
23	27	25	15	30	20	20	10	15	5	5	5	5	*	20	*	5
24	27	10	0	5	5	10	0	10	0	15	5	10	*	5	*	11
25	32	15	10	15	10	10	5	15	5	15	5	15	*	15	*	14

26	36	20	0	20	0	20	0	15	0	15	5	15	*	5	*	18
27	29	25	15	25	15	25	20	25	20	15	5	15	*	25	*	15
28	21	25	15	20	15	35	20	35	30	20	10	20	*	30	*	18
29	30	15	15	20	15	25	15	25	15	20	10	15	*	20	*	18
30	32	25	15	25	15	25	15	25	15	20	5	15	*	20	*	18
31	21	15	5	15	5	10	10	15	5	20	5	20	*	10	*	16
32	27	20	5	20	5	15	10	25	5	10	10	15	*	25	*	13
33	35	25	10	25	10	25	10	30	15	15	15	20	*	20	*	18
34	21	20	5	15	5	15	15	10	10	10	10	20	*	15	*	13
35	26	20	15	15	10	20	15	10	10	10	10	15	*	20	*	13
36	21	20	10	25	15	30	25	25	15	20	10	20	*	20	*	18
37	30	20	20	20	10	15	10	15	10	20	10	15	*	15	*	18
38	22	20	10	20	10	25	20	30	15	5	0	5	*	25	*	13
39	21	20	10	20	10	15	10	10	10	5	0	5	*	5	*	9
40	27	20	15	20	10	15	15	15	15	5	5	5	*	15	*	5
41	27	25	15	30	20	20	10	15	5	15	5	10	*	20	*	11
42	32	10	0	5	5	10	0	10	0	15	5	15	*	5	*	14
43	36	15	10	15	10	10	5	15	5	15	5	15	*	15	*	18
44	29	20	0	20	0	20	0	15	0	15	5	15	*	5	*	15
45	21	25	15	25	15	25	20	25	20	20	10	20	*	25	*	18
46	30	30	20	30	20	45	25	45	35	20	10	15	*	35	*	18
47	32	15	15	20	15	25	15	25	15	20	5	15	*	25	*	18
48	21	25	15	25	15	25	15	25	15	20	5	20	*	20	*	16
49	26	15	5	15	5	10	10	15	5	20	10	15	*	10	*	16
50	23	15	15	15	15	15	15	15	15	10	5	10	*	30	*	9
51	21	15	5	15	5	10	10	20	5	5	0	5	*	10	*	8
52	22	15	15	20	15	10	10	20	15	5	0	5	*	10	*	13
53	21	20	10	15	10	25	15	20	15	5	0	5	*	25	*	9
54	23	20	5	20	5	15	15	15	15	5	0	5	*	10	*	10

55	27	20	10	15	5	15	10	15	10	10	5	5	*	5	*	9
56	39	15	15	15	15	10	5	10	10	5	5	5	*	10	*	6
57	35	10	5	15	5	15	10	10	5	10	5	10	*	20	*	11
58	24	10	10	10	10	10	10	10	0	15	5	10	*	15	*	13
59	40	10	10	15	5	20	10	15	5	20	15	15	*	10	*	14
60	26	10	10	10	10	10	5	10	5	10	10	15	*	25	*	9
61	27	15	5	15	15	15	15	15	15	15	5	10	*	15	*	9
62	27	15	5	10	5	5	5	5	0	5	5	5	*	0	*	5
63	27	20	15	25	15	15	10	15	5	15	5	10	*	20	*	11
64	32	10	0	5	5	10	0	10	0	15	5	15	*	5	*	14
65	36	15	10	15	10	10	5	15	5	15	5	15	*	15	*	18
66	29	20	0	20	0	20	0	15	0	15	5	15	*	5	*	15
67	21	25	15	25	15	25	20	25	20	20	10	20	*	30	*	18
68	30	30	20	30	20	45	25	45	35	20	10	15	*	40	*	18
69	32	15	15	20	15	25	15	25	15	20	5	15	*	25	*	18
70	21	25	15	25	15	25	15	25	15	20	5	20	*	20	*	16
71	27	15	5	15	5	10	10	15	5	10	10	15	*	10	*	13
72	35	20	5	20	5	15	10	25	5	15	15	20	*	30	*	18
73	21	25	10	25	10	25	10	30	15	10	10	20	*	20	*	13
74	26	20	5	15	5	15	15	10	10	10	10	15	*	15	*	13
75	21	20	15	15	10	20	15	10	10	20	10	20	*	25	*	18
76	30	20	10	25	15	30	25	25	15	20	10	15	*	30	*	18
77	22	20	20	20	10	15	10	15	10	5	0	5	*	15	*	13
78	21	25	10	25	10	30	25	35	20	5	0	5	*	30	*	9
79	26	20	10	20	10	15	10	10	10	20	5	20	*	5	*	16
80	23	20	15	20	10	15	15	15	15	20	10	15	*	15	*	16
81	21	15	5	15	5	10	10	15	5	10	5	10	*	10	*	9
82	22	15	15	15	15	15	15	15	15	5	0	5	*	30	*	8
83	21	15	5	15	5	10	10	20	5	5	0	5	*	10	*	13

84	23	15	15	20	15	10	10	20	15	5	0	5	*	10	*	9
85	27	20	10	15	10	25	15	20	15	5	0	5	*	25	*	10

C. KEY TO MASTER CHART

E-Excellent

AA-Above Average

A-Average

BA- Below Average

Y /N– Yes/ No

L/N – Low/Normal

WD- Without Difficulty

D- Difficulty

AC - Air Conduction

BC - Bone Conduction

Hz - Hertz

dB - Decibels