Module 1

Occupational Audiometry Testing

Background & General Overview to Audiometry

Chapter 1

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Background and General Overview of Audiometry

Chapter Outline

Anatomy of the ear	Mechanism of hearing
Types of audiograms in occupational health	Components of the audiometry protection programme
Quality assurance in audiometry	Type 4 audiometer characteristics
Calibration of PTAC	Acoustic Environment
Employee preparation	Conducting an audiogram
What does an audiogram look like	Four main types of hearing loss
Interpretation	Recording
Reliability	Validity
Reporting	Management

Educational Aims

After studying this educational content, you should be able to:

- ✓ Relate a brief history of occupational audiometry
- ✓ Describe an overview on the anatomy of the ear and physics of sound
- ✓ Define types of audiograms found in the occupational health setting
- ✓ Describe an overview of the hearing conservation programme
- ✓ Describe an overview of quality assurance in audiometry including equipment, acoustic environment, preparation of the employee
- ✓ Describe how to conduct an audiogram
- ✓ List the measurements of an audiogram
- ✓ List four main types of hearing loss
- ✓ Describe the steps of interpreting the audiogram
- ✓ Describe the recording on an audiogram
- ✓ List the importance of reporting on the audiogram

Background

The Occupational Health and Safety (OHS) Act and Regulations, Act No. 85 of 1993[1], along with the Mine Health and Safety Act, Act No. 29 of 1996[2], mandate the identification, monitoring, and control of all workplace hazards. environment for all employees.

In 1994, The Leon Commission of Inquiry conducted an investigation into occupational health and safety within the South African mining industry. The Commission's findings revealed that approximately 40% to 80% of employees involved in drilling operations experienced hearing loss after a decade of exposure. Furthermore, the Commission estimated that as much as 18% of cases of adult-onset hearing loss in the 20 southernmost countries in Africa (AFR-E region), which includes South Africa, were attributable to occupational noise exposure[3].

Hearing is an integral aspect of an adult's effective functioning within the work environment. Many workplaces require employees to have a functional sense of hearing for both their safety and optimal job performance. Workplace noise represents a tangible hazard that necessitates management through a structured hierarchy of control measures. While elimination of noise is the preferred approach, it may not always be attainable. Therefore, audiometry is employed in the workplace to evaluate the hearing threshold levels of individuals who are exposed to noise levels exceeding specified thresholds. This assessment is conducted to gauge how workplace noise impacts each individual, with the primary objective of hearing conservation, facilitating early diagnosis and management of hearing loss resulting from occupational noise exposure.

Audiometry is defined as the procedure to be followed in the testing of the hearing level of an individual and includes an otoscopic examination[4]. The outcome of an audiometric examination is represented through an audiogram, which is the handwritten or digitally produced record of those faintest sounds that a person can hear at specific frequencies. The audiogram adheres to internationally standardised formats and is typically displayed in the form of a chart, or graph and a numerical table. These measurements indicate the hearing threshold levels as a function of frequency (namely 0.5, 1, 2, 3, 4, 6 and 8kHz) as determined using a monoaural, pure – tone, air conduction threshold test and / or other diagnostic test methods.

Occupational screening audiometry is conducted by an audiometrist who possesses a certificate of competence in audiometry and maintains registration with Department of Employment and Labour (DoEL) via the Audiometry Register overseen by the South African Society of Occupational Health Nursing practitioners (SASOHN)[5].

The purpose of this course is to train individuals to become competent audiometrist and/or assistant who possess a comprehensive understanding of occupational audiometry. They should be capable of conducting consistent, reliable, and standardised audiometric screening procedure resulting in various valid types of occupational health audiograms.

In some instances, employees with certain pathologies are not able to achieve accurate results in automated audiometry. Consequently, it is essential for the audiometrist to be able to conduct both manual and automatic audiometry.

This requirement is also in alignment with the previous HWSETA unit standard and forthcoming QCTO skills program for professional practice in South Africa. Similarly, various other hearing professional societies and/or international health councils expect this of the audiometrist (technician)/assistant/occupational health practitioner/audiologists' assistant (audiometrician)/industrial audiologists. These societies and councils include: South African Society of Occupational Health Nursing (SASOHN); South African Association of Audiologists (SAAA); South African Speech Language and Hearing Association (SASHLA); Canadian Centre for Occupational Health & Safety (CCOHS); International Commission of Occupational Health (ICOH), etc.

Brief history of occupational audiometry

According to Workplace Medical Corp.[6] noise is a common phenomenon in our everyday lives. Going back to as early as the 6th Century BCE, the Greeks were pioneers in introducing noise regulations. To prevent disruption to the city's inhabitants, individuals like potters, tinsmiths and even roosters were relocated beyond the city walls. Furthermore, to maintain tranquillity during the night, a prohibition was enforced against wagons and carriages traversing the streets after sunset. These historical measures underscore the fact that people have long been annoyed with noise in their environment.

Hippocrates stands as one of the early observers who made a connection between tinnitus and prolonged exposure to noise. Moreover, healthcare professionals of that era recognized that certain occupations, like coppersmiths and blacksmiths, were notably associated with hearing impairment. With the advent of the Industrial Revolution, noise levels experienced a significant surge, especially with the introduction of the steam train. This era marked a turning point in the understanding of noise-related health issues.

In 1886, the initial comprehensive investigation into noise-induced hearing loss was conducted[6]. This study provided conclusive evidence that exposure to noise resulted in auditory impairments.

Alexander Graham Bell invented the first audiometer in 1879 initiating the practice of physicians evaluating hearing loss. However, it wasn't until 1890, that the inaugural Society for Suppression of Noise in London was established with the aim of mitigating noise exposure and, consequently, preventing noise-induced hearing loss. The society was established in response to the nuisance caused by the recently introduced car horn.

During the 1950's, the introduction of jet planes contributed to the noise pollution. Complaints of tinnitus, hearing loss, sleep interruptions, fatigue and stress were received from employees and the communities living near airports. In these same years some mining, and steel workers, (in some developed countries) received hearing protection and hearing tests from their employers. A series of discoveries and observations lead to recognition of noise as a dangerous substance by the Occupational Safety and Health Administration in 1971. This recognition served as a catalyst for the establishment of hearing conservation programmes[6].

In the late 1980s, significant steps were taken in Europe and the United States to address workplace noise. The 1989 Noise at Work Regulations, for instance, required industries to measure and assess noise levels in the workplace. It mandated the screening of employees and the provision of protection to prevent hearing loss. Additionally, the advent of more accurate electronic audiometers, equipped with advanced software, in the 1990s greatly facilitated compliance with these regulations and improved hearing protection measures.

In South Africa, a comprehensive framework of legislation, guidelines, and codes has been established to ensure the safety and health of employees in the workplace. This framework includes specific provisions for addressing noise-induced hearing loss as a recognized occupational disease. The subsequent chapters provide a more detailed exploration of the relevant legislation and its implications for both employers and employees. By adhering to these legal guidelines, we can work towards creating safer and healthier work environments for all.

Anatomy of the ear and mechanism of hearing

The audiometrist/assistant needs to understand the working of the ear and/or hearing as covered in detail in order to manage the audiometric process and/or interpret the audiogram. Briefly, the ear is divided into 3 sections: The outer ear, middle ear and inner ear. Each section consists of anatomical structures, which ultimately connect the pinna (ear lobe) to the sensorial neural pathway as innervated by the 8th Cranial nerve. Each section and subsequent anatomical structures have a distinct function in the mechanism of hearing that influences what hearing threshold limit, is eventually detected by the employee being tested and consequently reflected on the audiogram.

See Figure 1.1 and Figure 1.2 below for the structures and mechanism of hearing.

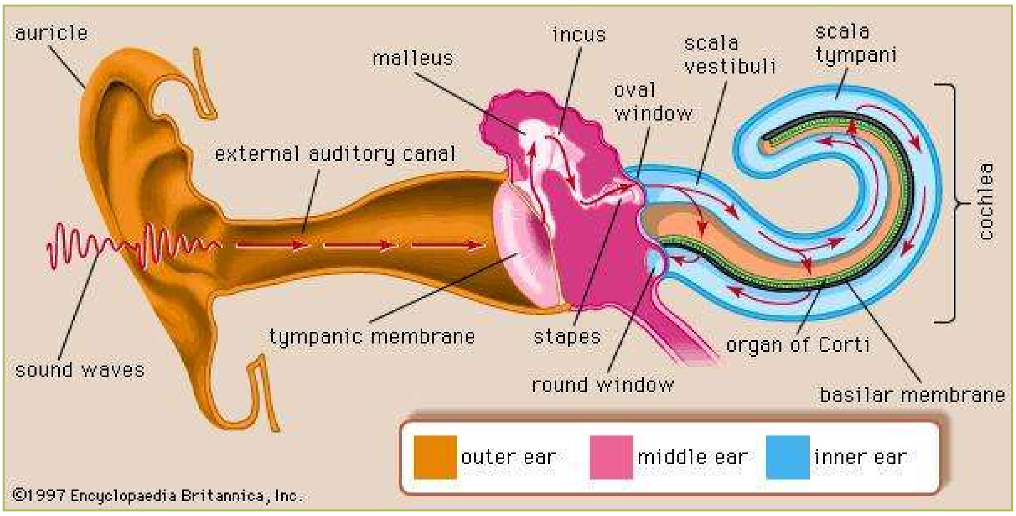

Figure 1.1: Mechanism of hearing[7]

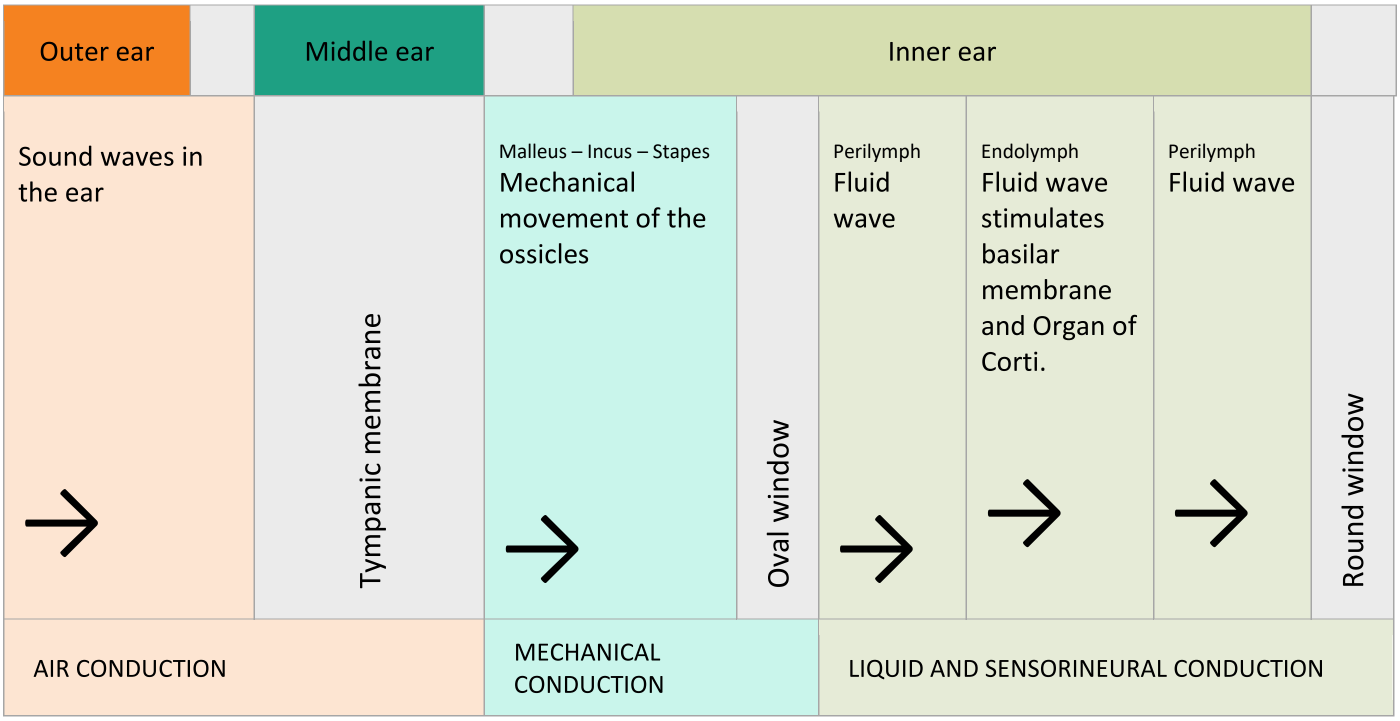

Figure 1.2 Transmission of sound waves[8]

Types of audiograms in occupational health

Audiometric testing in the occupational setting is performed as part of the occupational health surveillance programme for all employees exposed to noise equal to or above the noise rating limit of 85dB(A) and/or at a noise rating level which hearing impairment is likely to occur. The requirements of the various audiograms are specified in the:

- ✓ OHS Act No. 85 of 1993[1] (including Noise-Induced Hearing Loss Regulations[5])
- ✓ MHS Act No. 29 of 1996[2] (including R839[9])
- ✓ COID Act No. 130 of 1993[10] (including Instruction 171)
- ✓ SANS 10083[4]

Table 1.1: The names of Audiograms as denoted in Legislation[1 2 4]

Legislative name of the occupational audiogram	Source: MHS Act No. 29 of 1996	Source: OHS Act No. 85 of 1993 NIHL R307 of 2003 COIDA No 130 of 1993	Source: SANS 10083:2021
Baseline	Baseline	Baseline	Baseline
Entry	Milestone Baseline		
Periodic	Periodic	Periodic	Periodic
Monitoring	Monitoring		Entry level
Exit	Exit	Exit	Exit
Diagnostic	Diagnostic		Diagnostic
	Initial		

Components of the hearing conservation programme

The key components of a workplace audiometry test program should be clarified before performing audiometry testing and should include:

- ✓ The purpose of the audiometry testing
    - Occupational health surveillance (to detect abnormalities)
    - Appropriate job placement (after hire, before job placement)
    - Component of health assessment for personal protective equipment (PPE) usage
    - Component of an impairment or disability evaluation
- ✓ Defined parameters for the audiometry testing program
    - Noise exposures and ear diseases of concern
    - Regulatory and workplace-mandated requirements
    - Frequency of testing
    - Employees to be tested (based on potential hazards or other concerns)
- ✓ Responsibility for evaluation and feedback of data for

- The individual employee
- Management: aggregate analysis of the audiometry testing and other data collected on the group of employees

- ✓ Lines of communication of relevant information between the employee, employer, and healthcare provider
- ✓ Operator training standards: To optimize the quality of audiometry testing, operators should undergo training and refresher courses. They should also receive on-going feedback about the quality of tests that they perform, and how to correct problems in test performance
- ✓ An effective quality assurance program
- ✓ Define appropriate audiometry testing reference values and interpretative strategies
- ✓ Establish triggers for further intervention and management of audiometric results

Quality assurance in audiometry

Quality assurance[11] is an integral component of the ***quality management*** process and encompass the establishment of standards, guidelines and procedures. These measures are designed to pre-empt quality issues and uphold the integrity of the product and/or service. The primary objective is to sustain these standards and seek to improve the performance of all aspects of audiometry testing in the workplace. This provide reassurance to all parties involved, that a high-quality service is rendered.

Quality assurance and quality control is often confused. Quality assurance and quality control is both integral component of methods and tools to manage all aspects of ***quality management***:

- ✓ Quality assurance is primarily concerned with devising plans and strategies to avert potential risks that could impact the quality of a product or service (equipment calibration, etc)
- ✓ Quality control focus around the evaluation and testing of the quality of the output once the product or service has been provided (your audiogram)

Five components contribute to the quality assurance of audiometry and include

- ✓ Equipment maintenance procedures
- ✓ Environmental preparation
- ✓ Employee preparation
- ✓ Operator training requirements
- ✓ Quality assurance review process

Characteristics of a Type 4 audiometer[4]

- ✓ Pure Tone screening audiometer
- ✓ Testing frequencies 500, 1000, 2000, 3000, 4000, 6000, 8000 Hz
- ✓ Able to test 0 – 70dB
- ✓ Calibration certificate of compliance with SANS 10154[12]
- ✓ Equipped with two earphones marked for left and right ears
- ✓ Output level control (a non-auditory warning indication to the operator for setting above 100d B hearing level
- ✓ Test signal switching presentation/interruption
- ✓ Equipped with an employee response button
- ✓ Able to conduct manual and automated tests

Calibration of Puretone Audiometers

Calibration of screening equipment is essential to ensure accurate, reliable, and valid test results. Calibration is the process of measuring the equipment against a known standard measurement as per SANS 10154-1:2012[12].

CALIBRATION TYPES:

1. Electro-Acoustic
2. Subjective Testing
3. Daily Functional Checks

Acoustic Environment

According to SANS 10182:2006 ***The measurement and assessment of acoustic environments for audiometric tests,*** an acoustic environment is defined as "a room, booth or mobile facility in which audiometric tests are conducted"[13]. SANS 10182 requires that specific environmental noise level criteria be met at each frequency (octaves from 125Hz to 8kHz) while an audiometry test is conducted.

Employee preparation

History Taking for Audiometry

Before an audiogram is done, a thorough history should always include:

- ✓ The demographics of the employee being tested
- ✓ The occupational history (past and present)
- ✓ Current work-related exposures
- ✓ Medical history
- ✓ Surgical history
- ✓ Trauma history
- ✓ Hereditary history
- ✓ Recreational exposures

NB: History Taking (ENT specific)

- ✓ Demographics
- ✓ Occupational History
- ✓ Current work-related exposures
- ✓ Medical History
- ✓ Surgical History
- ✓ Trauma History
- ✓ Hereditary History
- ✓ Recreational History

Otoscopy

Otoscopy consists of a physical examination of the outer ear and an inspection using the otoscope up until the tympanic membrane. Otoscopy is a critical element of audiometry. The environment for the physical examination should be arranged to be as private as possible. Lighting should be adequate, and equipment should be arranged on a clean surface. The employee should be prepared for the physical examination with a clear description of what will be completed. In addition, all required tools, including an otoscope need to be readily available.

The purpose of the otoscopic examination is to evaluate the condition of the ear canal, tympanic membrane, and the middle ear. The ear canal and tympanic membrane are not easy to examine because of their relative inaccessibility and the need for both magnification and illumination. The examiner's skill with an otoscope depends on a practical understanding of the anatomy of the ear, a suitable choice of otoscope and speculum, and a reliable examination technique. Otoscopy should be carried out prior to any audiometry[4]. The examiner should be able to identify the normal features of the tympanic membrane (TM).

Manual testing method[14,15]

Manual audiometry is the benchmark standard for clinical testing. The audiometrist controls the signal frequency, intensity, and presentation. The audiometrist / assistant follows a standard procedure for presenting the test signals. By observing intensities to which the employee responds and those intensities for which there is no response, the audiometrist / assistant determines the signal intensity at threshold for each test frequency and records it on an audiogram table and chart. This is done when the audiometrist / assistant tests the employees hearing by presenting the tone, adjusting the frequency (Hz) and decibels (dB). The procedure used to test an individual is called the Hughson-Westlake or ascending method. The key points of this method are:

- ✓ When the employee hears the tone –⇩ ***decrease*** the intensity with ***10dB*** **-** softer
- ✓ When the employee does not hear the tone -⇧ ***increase*** the intensity with ***5dB*** **–** louder
- ✓ Seeking the lowest intensity (dB level) at which the employee hears the tone and responds
- ✓ The employee must respond 3 times at the lowest level possible heard by the employee for the result to be recorded as the hearing threshold level.

Automated testing method

The Type 4 audiometer is equipped with a standardised internal program designed to automate the Hughson-Westlake method. The role of the audiometrists involves closely monitoring the employee's consistency in responses to the test signal, in order to prevent undue malingering (potential exaggeration) or equipment induced temporary threshold shift (TTS). When the employee encounters difficulties with specific frequencies, the audiometrist then need to revert to manual method for more precise assessment.

Recording the audiogram

Audiometric findings are documented in both tabular and graphical formats. Below is an example of a standard air conduction pure tone audiogram showing hearing levels falling within the range of normal to mild hearing loss.

- ✓ The circles represent the right ear and are charted in red
- ✓ The crosses represent the left ear and are charted in blue
- ✓ Decibels run down the left of the graph (zero at the top and 90 at the bottom)
- ✓ Decibels increase in fives and tens represented by the lines for 10's and in the middle of the block are the 5's
- ✓ Frequencies go across the top of the graph

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- ✓ The different hearing thresholds are connected with a line – all the red circles for the right ear and all the blue crosses for the left ear to show the configuration of the hearing test result

SANS 10083:2021[4] Annexure B deals with audiometry reports and states what information is required on each audiogram. Each type of audiogram has specific information, which is critical to ensure a legal document.

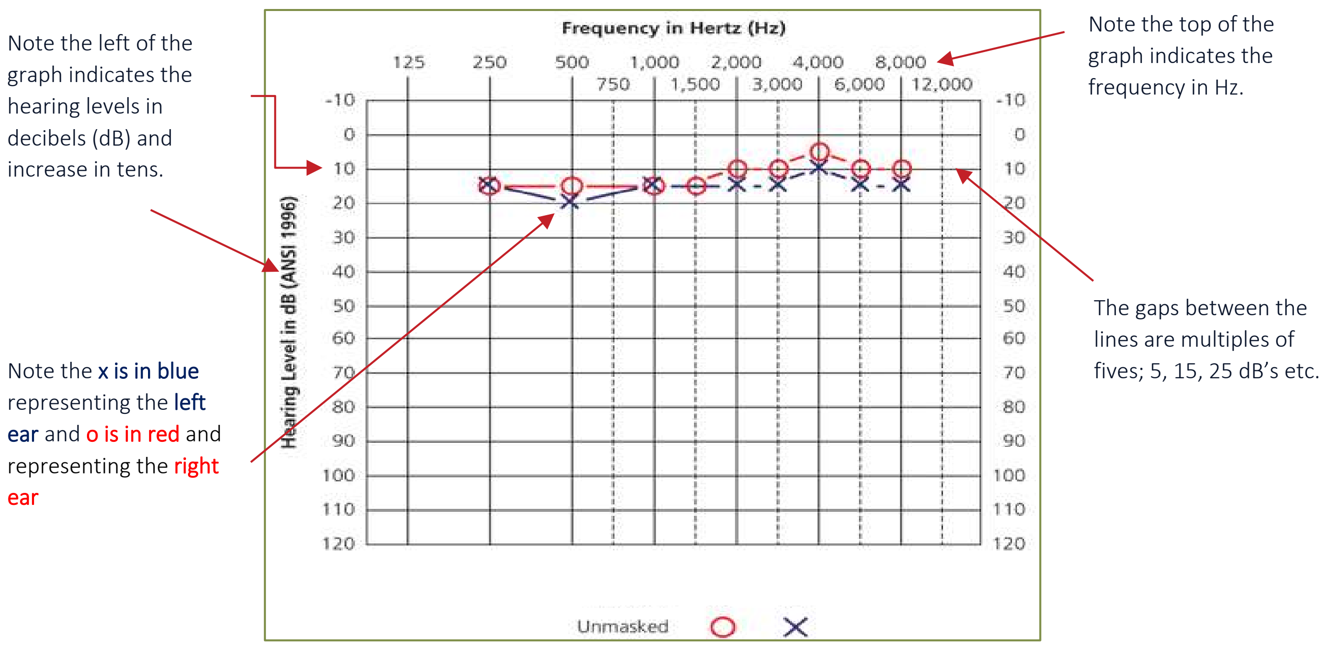

Figure 1.3: An example of a screening audiogram[16]

Characteristics of the 4 main types of hearing loss

- ✓ Conductive hearing loss
- ✓ Sensori-neural hearing loss
  - Noise Induced Hearing Loss
  - Presbycusis
- ✓ Mixed hearing loss
- ✓ Auditory Neuropathy Spectrum Disorder

Before the interpretation of an audiogram can be completed, certain calculations need to be done to determine:

- ✓ The percentage loss of hearing

- ✓ The percentage loss of hearing shift
- ✓ In mining the milestone baseline or audiometric zero must be calculated
- ✓ In mining the standard threshold shift (STS)must be calculated from the audiometric zero
- ✓ Referral Threshold Shift (RTS)

Most audiometers with software support automatically perform these calculations on behalf of the audiometrist. However, when performing manual audiometric testing methods, the audiometrist or assistant must manually calculate these results once the hearing thresholds have been established. Audiometric software does not distinguish between mining and non-mining employees therefore it is important for the audiometrist to capture the correct demographical information into the software and select the appropriate type of audiogram for each employee. This ensures that the correct calculations and classifications are applied based on the specific occupational health context.

Evaluate the audiogram

This involves evaluating the reliability and validity of the type of audiogram done. Reliability criteria ensures that consistent and accurate results are recorded and the validity of the type of audiogram refers to the legislated requirements for each specific occupational audiogram.

Interpretation

The primary objective of occupational audiometry testing is to accurately measure and employee's hearing threshold levels and to detect and manage threshold shifts that may occur. In the context of occupational health, audiometry can assess an employee's suitability for work and determine their eligibility for compensation in cases of noise-induced hearing loss. For this reason, interpretation is a critical step for the audiometrist. When interpreting an audiogram, the report guides the audiometrist on the presence of hearing loss, the type of hearing loss, the configuration of the hearing loss (which frequencies are affected), and the degree of hearing loss (severity).

Audiometrists/Assistants are <u>not</u> required to make a medical diagnosis but **are still required to identify certain hearing loss patterns**, specifically noise induced hearing loss patterns, in order to appropriately action and/or manage the cases. To do this effectively and accurately, interpretation of the results involves integrating the history obtained, the otoscopy findings, the PLH, the PLHS, the RTS, the STS, the severity of hearing loss on the graph, and the configuration (shape) and the hearing loss pattern on the graph.

Prior to interpreting an audiogram, it's important to emphasize that the interpretation process is not solely based on visual analysis of the graph. It requires a comprehensive evaluation involving the analysis, integration, interpretation, and assessment of all available information at the time of the assessment, including the following:

- ✓ Full medical, surgical, and social history
- ✓ Full occupational history
- ✓ The otoscopic examination
- ✓ The noise free period before testing
- ✓ The audiogram
- ✓ The comparison to the baseline test as well as any other available audiograms

Analysis of the audiogram – 10 Actions

1. Quality control
2. Demographic detail
3. History
4. Audiometric test and validity criteria
5. Otoscopic examination
6. Audiogram
7. Interpretation
8. Management
9. Document storage
10. Signature and date

Records

The Occupational Health and Safety Act No. 85 of 1993, the NIHL Regulation (R307 of March 2003) and the Mine Health and Safety Act No 29 of 1996 prescribe that the following audiometry records should be kept for a period of 40 years[1]:

- ✓ Noise assessments and monitoring records
- ✓ Occupational health surveillance records
- ✓ All training records and material regarding noise, noise induced hearing loss and noise exposure
- ✓ All reports pertaining to referrals to specialists (audiologists and ENT's), and submissions to the compensation commissioner and various inspectorates (DoEL and DMRE)

Reports

Good quality, accurate and professional medical records are an essential component of safe and effective occupational healthcare. The main functions of medical records are to facilitate:

- ✓ Continuity of care
- ✓ Recordings decision made regarding care and management
- ✓ Trend analysis
- ✓ Preventing exploitation and
- ✓ Support with litigation

Management of the audiometric result and referral

Once the audiogram has been conducted and interpreted the appropriate management of the case is essential in preventing occupational hearing loss. A multidisciplinary team approach is necessary for managing hearing conservation in the workplace. Management should include appropriate actions as indicated by legislation, standards, and guidelines.