CLASSROOM ACOUSTIC MEASUREMENTS AND AUDIOLOGICAL SCREENING OF YEAR 1 SCHOOL CHILDREN

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UNIVERSITI SAINS MALAYSIA

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CLASSROOM ACOUSTIC MEASUREMENTS AND AUDIOLOGICA SCREENING TEST OF YEAR 1 SCHOOL CHILDREN

By

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Dedication

To my late father and my late mother

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List of Abbreviation

AABR	Automated Auditory Brainstem Response
AAP	The American Academy of Pediatrics
ANSI	American National Standards Institute
ASHA	American speech hearing association
CDP	Centers for disease and prevention
Db	Decibel
DPOAE	Distortion product otoacoustic emissions
DS	Discrimination score
FM	Frequency Modulated
HPL	Half peak level
HSV	Herpes Simplex Virus
HVCA	Heating, ventilating and air-conditioning
Hz	Hertz
IAC	Industrial Acoustic Company
IPH	Institute for public health
MSHL	Minimal sensorineural hearing loss
OAE	Otoacoustic emission
ODS	Optimum discrimination score
OME	Otitis media effusion
PB	Phonetically balanced
PE	Pressure equalization
PTA	Pure tone audiometer
RT	Reverberation time
RTI International	Research Triangle Park, North Carolina
SD	Standard deviation
Sec	Second
SFOE	Sustained-frequency otoacoustic emissions
SLM	Sound level meter
SNR	Signal to noise ratio
SOE	Spontaneous otoacoustic emissions
SRI Aman	Sekolah Rendah Islam Aman
SKKK2	Sekolah Kebangsaan Kubang Kerian 2
SRT	Speech reception threshold
TOE	Transient otoacoustic emissions
UHL	Unilateral hearing loss
WHO	World Health Organization

PENGUKURAN AKUSTIC BILIK DARJAH DAN SARINGAN AUDIOLOGI DALAM KALANGAN KANAK-KANAK TAHAP UMUR MASUK- SEKOLAH

ABSTRAK

Bunyi bising dikaitkan dengan kemerosotan kualiti hidup dengan mengganggu percakapan, mempercepatkan dan meningkatkan perkembangan sikap sosial negatif seperti meragam dan neurosis, dan juga gangguan penumpuan dan seterusnya prestasi dan produktiviti. Dalam kelas, persepsi bunyi dikaburi oleh ambien bunyi bising dan gema*(reveberation)*. Gema berlebihan dan ambien bunyi bising mempunyai kesan negatif yang jelas terhadap persepsi percakapan melalui bunyi yang dicemar (*smearing)* atau penopengan (*masking)*. Walaupun kehilangan pendengaran adalah perkara biasa dan ketidakupayaan yang biasa berlaku yang mengganggu prestasi pembelajaran kanak-kanak yang bersekolah dalam negara membangun, kanak-kanak dalam era persekolahan jarang disaring pendengaran mereka sewaktu pemeriksaan klinikal rutin, dan pihak berkuasa bidang kesihatan tidak menumpukan sepenuh perhatian terhadap penilaian audiometrik terutamanya di sekolah rendah. Ini berlaku disebabkan kekurangan pengetahuan dalam kalangan ibu bapa, pihak sekolah, dan pihak kesihatan terhadap akibat kehilangan pendengaran. Oleh sebab itu, saringan pendengaran dalam kalangan pelajar sekolah telah dicadangkan untuk pengesanan lebih awal dan proses pembaikpulihan pelajar sekolah yang hilang pendengaran di negara-negara membangun. Objektif utama kajian ini adalah untuk menguji pengukuran akustik dalam kelas dan status pendengaran dalam kalangan kanak-kanak peringkat permulaan persekolahan.Kajian ini mengandungi tiga bahagian. Bahagian pertama kajian ini adalah mengenai pengukuran pengecilan bunyi di kabin bunyi dirawat manakala

bahagian kedua kajian ini mengukur tahap bunyi dan masa gema di dalam kelas yang dipilih di sekolah. Bahagian akhir kajian ini adalah bahagian yang paling penting di mana status telinga dan pendengaran kanak-kanak sekolah disaring. Ini dilakukan dengan memilih dua buah sekolah rendah yang mana salah satu daripada mereka adalah sekolah harian dan yang satu lagi sekolah swasta. Kebisingan diukur menggunakan meter tahap bunyi pada tahap 5 di setiap kelas. Pengukuran bunyi gema dilakukan menggunakan perisian Sound Forge. Data yang diperolehi menunjukkan nilai pengecilan bunyi jalur lebar pada tahap kekuatan yang berbeza untuk dua jenis kabin bunyi dirawat adalah hampir sama. Pengecilan nada tulen pada frekuensi rendah berbeza (250, 500 dan 1000 Hz) untuk dua kabin bunyi dirawat itu menunjukkan kabin bunyi dirawat buatan UK mempunyai nilai pengecilan lebih tinggi berbanding buatan tempatan, terutamanya pada kadar intensity yang tinggi. Untuk nada frekeunsi tinggi, nilai pengecilan untuk kedua-dua kabin bunyi dirawat adalah lebih kurang sama pada semua intensiti . Bagi pengukuran tahap kebisingan, kebisingan dalam kelas di sekolah swasta adalah lebih rendah daripada kelas di sekolah kerajaan. Secara keseluruhannya, purata tahap kebisingan dalam kelas di sekolah swasta adalah di antara 52.1hingga 67.6 dBA dan purata tahap kebisingan dalam kelas di sekolah kerajaan adalah daripada 54.8 hingga 76.7 dBA. Bagi ukuran bunyi gema pula purata masa yang diperolehi daripada kajian ini adalah 0.5+0.05 saat di sekolah swasta dan 0.76+0.16 saat di sekolah kerajaan. Bagi pemeriksaan telinga dan pendengaran kajian keratan rentas ini dijalankan di dua sekolahdi Kota Bharu, Kelantan. Sejumlah 227 orang pelajar dengan purata umur 6.5 tahun (6-7 tahun) mengambil bahagian dalam kajian ini.Kedua-dua belah telinga diperiksa menggunakan otoskop, DPOAE, timpanometri dan audiometer nada tulen.

Sebanyak 454 telingat diperiksa, dan pemeriksaan otoskopik menunjukkan 101 telinga kanan yang dan 95 telinga kiri yang abnormal dan yang paling kerap didapati adalah lelilin telinga dan otitis media hidup effussion. Tiga puluh sembilan (17.2%) DPOAE dirujuk, di mana16 (7%) telinga kanan dan 11 (4.8%) telinga kiri manakala kedua-dua telinga dirujuk dalam 12 (5.2%) pelajar. Timpanometri adalah abnormal dalam 66 (50.2%) telinga kanan dan 60 (26.4%) telinga kiri. Nada tulen audiometeri (PTA) menunjukkanbahawa 113 (50.2%) telinga kanan dan 125 (55.5%) telinga kiri mengalami kurang pendengaran pada satu frekuensi. Apabila taha pendengaran diperiksa menggunakan PTA dengan menggunakan empat frekuensi (500, 1000, 2000 dan 4000 Hz), 31 (13.6%) pelajar didapati mengalami kurang pendengaran, 28 daripada mereka mengalami kurang pendengaran tahapsedikit dan tiga daripadanya sederhana. Kurang pendengaran adalah bilateral dalam 14 (6.2%) kanak-kanak dan 6 (2.6%) dalam telinga kiri, 11 (4.8%) dalam telinga kanan. Apabila kesahihan DPOAE sebagai alat penyaringan diteliti terhadap PTA, ia menunjukkan 95% sensitiviti dan spesifisiti adalah 59%. Secara kesimpulan, penyaringan rutin berdasarkan pengenalpastian keadaan telinga akan membantu pengesanan kurang pendengaran dalam kalangan kanak-kanak yang bersekolah kerana ia boleh dirawat pada peringkat awal untuk mengelakkan kemungkinan komplikasi dan kesannya terhadap sikap dan pendidikan mereka.

ABSTRACT

Noise is connected to a deteriorating quality of life, by interfering with speech, by accelerating and escalating the development of negative social behaviors such as irritability and neurosis, as well as interferes with attention and consequently performance and productivity. In classrooms the sound perception is obscured by ambient noise and reverberation. Excessive reverberation and ambient noise have a marked negative effect on speech perception by smearing or masking sound. While hearing loss is a common and considerable disability that harms educational performance of school children in developing countries unfortunately, school-aged children are rarely screened for hearing loss during routine clinical examination, and health authorities pay little attention to audiometric evaluation particularly in primary schools. This is usually attributable to the inadequate knowledge of parents, school authorities and healthcare providers on the outcomes of mild hearing loss. Therefore, hearing screening at school entry has been proposed for the early detection and rehabilitation of hearing impaired school children in the developing countries. The main objective of this study was to study the acoustic measurement of the classrooms and the status of hearing among children at entry school age. This study consisted of three parts. The first part of this study was about measuring the sound attenuation of sound treated booths while the second part of this study measured the noise levels and reverberation times in selected classrooms of the schools. The last part of this research was the main part whereby school children were screened for their ear and hearing status. This was

done by choosing two primary schools, a public and a private school. Noise was measured using sound level meter at 5 points in each classroom. Meanwhile the measurement of reverberation time was conducted using Sound Forge software. The data obtained showed that the attenuation values of broadband noise at different intensity levels for the two different sound treated booths were almost similar. The attenuation of pure tones at the lower frequencies (250, 500 and 1000 Hz tones) for the two sound treated booths showed that the UK made sound treated booth having higher attenuation values than the locally made, especially at higher intensity levels. For high frequency tones, the attenuation values for both sound treated booths were almost identical at all intensity levels. For the noise level, in classrooms at the private school is lower than the noise level in classrooms at the public school. Overall, the mean noise level in classrooms at the private school ranges from 52.1 to 67.6 dBA and the mean noise level in classrooms at the public school ranges from 54.8to 76.7 dBA. The mean reverberation time obtained from this study is 0.51± 0.05 seconds in private school and 0.76 ± 0.16 seconds in the public school. For the ear examination and hearing across sectional study was conducted in schools of Kota Bharu, Kelantan. A total of 227 student with a mean age of 6.5years (range 6-7 years) participated in this present study. Both ears were examined using otoscope, DPOAE, tympanometry and pure tone audiometer. Altogether 454 ears were examined, the otoscopical examination showed 101 abnormal right ears and 95 abnormal left ears and the most common finding was ear wax followed by otitis media with effussion . Thirty nine (17.2%) students failed (refer) DPOAE whereby 16(7%) in the right ear and 11(4.8%) left ear while 12(5.2%) were referred in both ears. Tympanometry was abnormal in 66(29%) right ears and

60(26.4%) left ears. The pure tone audiometry (PTA) showed that 113(50.2%) right ears and 125(55.5%) left ears has hearing loss in single frequency. When hearing impairment was examined with PTA the use of four frequencies 31(13.6%) students found to be impaired, 28 of them were mild and 3 moderately impaired. This impairment was bilateral in 14(6.2%) children and 6 (2.6%) in the left ear, 11(4.8) in the right ear. When the validity of DPOAE as a screening tool was examined against the PTA it showed a sensitivity of 95% and the specificity was 59%. In conclusion routine screening based on the identification of ear conditions will facilitate the detection of hearing impaired school-aged children which can be treated early to avoid possible complications and to avoid its impact on behavior and education.

CHAPTER ONE:

INTRODUCTION AND LITERATURE REVIEW

CHAPTER ONE

Introduction and literature Review

1.1 Introduction

1.1.1 Hearing

Hearing is very important for children at school age because if a child has hearing loss this will affect his or her learning, academic achievement, social relation and over all his connection to the outer world.

Hearing is essential as other senses. If without it, we can't enjoy the music, the sound of nature that uplifts us, or hear words from our loved ones, and many others. We communicate and become productive through hearing. Although hearing deteriorate with age, but we are in danger of losing the sense of hearing even in youth.

It is an important function for communication and provides people with enjoyable experiences such as listening to music. The loss of capability to hear has significant consequences in one's day to day life and ability to play a role within the hearing culture (Arehart *et al.*, 1998). Hearing is performed primarily by the auditory system vibrations are detected by the ear and transuded into nerve impulses that are apparent by the brain (primarily in the temporal lobe) in human beings and other vertebrates. The touch and hearing are types of mechano-sensation (Kung, 2005).

1.1.2 The effect of hearing loss

Losing hearing sensation can be quite troublesome and pass unnoticed for period of time before it is detected and if this phenomena happened at early stage of life can have long lasting effect on the individual affected by it.

All aspect of our life is affected by hearing loss, especially our most important personal and professional relationships which includes emotional, physical, mental and spiritual. Individuals suffer from hearing loss often separate themselves from community. Separation compounds the stress with depression, resulting in even greater hurt to overall health (Hendershot *et al*., 2011).

Devastating results can develop if hearing loss is present. Hence speech and language development depends on hearing, so children with hearing loss will not be noticed till it is late. The child with hearing loss may be considered a slow learner during his educational course. People with hearing loss may be socially isolated and difficult to communicate with. The most important thing is to have an early diagnosis of hearing loss with a backup of suitable follow-up, treatment and rehabilitation (Grogg and Grogg, 2007).

"In early life of infancy the moderate and severe hearing losses are associated with impaired language development (Ruben, 1991; Rach *et al.*, 1988). Family history of hearing impairment, congenital or central nervous system infections, ototoxic drug exposure, prematurity, congenital head and neck deformities, trauma, and a number of other factors associated with admission to an intensive care nursery are the factors that elevate the risk for congenital or delayed –onset of sensorineural hearing impairment"

(Prager *et al.*, 1987; Smith *et al.*, 1992; Parving, 1985). A younger age child with hearing loss lead to more serious effects on the child's development therefore we need for early detection of hearing loss and early intervention program. Less serious impact occurs with earlier recognition of the problem and intervention (Hendershot *et al*., 2011).

1.1.3 Major ways in which hearing loss affects children

There are several ways in which children are affected by the hearing loss, delay in the development of receptive and expressive communication skills (speech and language) which are caused by hearing loss. The reduced in academic achievement which is result from language insufficiency. Difficulties in communication mostly lead to isolation from society and poor self-concept. It may have an impact on vocational choices (Hendershot *et al*., 2011). The language is central to the child's ability to deal with internal motivation and external control (Schirmer, 2001).

1.1.4 Specific effects of hearing loss

Specifically hearing loss affect the vocabulary, sentence structure, speaking, academic achievement and social functioning.

1.1.4 (A) Vocabulary

A child who has hearing loss the vocabulary develops is slower. Children with hearing loss learn abstract words like before, after, equal to, and jealous more difficult than concrete words like (five, red, cat). They also face difficulty with function words like the, and a. The gap between the vocabulary of normal children and those with hearing problem widens with age. Children with hearing loss will not be able to close the gap without intervention. Understanding words with several meanings are difficult to Children with hearing loss.

1.1.4 (B) Sentence structure

Children with hearing loss comprehend and produce shorter and less complex sentence than children with normal hearing. They often have difficulty understanding and writing complex sentences, such as those with relative clauses (The teacher whom I have for math was sick today) or passive voice (The ball was thrown by Huda) and often cannot

hear word endings such as *-s* or *-ed*. This leads to misunderstandings and use wrongly of verb tense, possessives, nonagreement of subject and verb, and pluralization.

1.1. 5 Effect of back ground noise in the classrooms

Classrooms are usually noisy places, and children are more active than in past decades. In 2002 Knecht *et al.*, measured reverberation and background noise levels in 32 unoccupied elementary classrooms in eight public school buildings in central Ohio in eight public school buildings. Background noise levels ranged from 32 to 67 dBA while the noisiest classrooms were those with noisy heating, ventilating and air-conditioning (HVAC) units running, most of the classrooms were noisy even when the HVAC systems were turned off. Significant noise was measured from other internal equipment and from intrusions from hallways and outdoors. Overall, these examples show excessive noise from HVAC units, from adjacent classrooms through temporary partitions, and from hallways through ill-fitting classroom doors. These types of noise intrusions occur frequently and are typical of classroom situations. Reverberation in classrooms arises from sound reflecting off of hard walls and high ceilings. In rooms with hard surfaces, sound reflects, causing a persistence of the sound after the source itself stops. Excessive reverberation "smears" the temporal properties of speech signals. Instead of individual distinct speech sounds following one after another in words, the reverberation makes the sounds overlap each other, causing them to be more difficult to understand.

In Malaysia the classrooms are typically more "open" with windows and doors always open to decrease the temperature and humidity in the class thus decreasing the chance of reverberation. However, sound of ceiling fans add to the background noise besides the road traffic noise.

1.1.6 Purpose of the school hearing screening and threshold testing program

"School hearing screening and threshold testing program is performed to identify children with hearing impairments. Such a program is part of a total hearing conservation and rehabilitation effort and aids in the teaching of the avoidance of hearing loss, planning for medical treatment, and educational programs for the child with significant loss. The possibility of a hearing loss can be noticed from the child's behavior in the classroom. The child may ask for repetition always and may score low in his tests. The observation of such behavior will help in suspecting children in need for assessment of hearing levels (Elden and Potsic, 2002).

Most of these children with hearing impairment are in need of medical treatment, such treatment may result in return of hearing and avoidance of permanent hearing impairment" (Niskar *et al.*, 2001).

This screening programme was expanded to include the screening of 3 year old and new entrant children with tympanometry in 1980's. A pilot in Canterbury and Otago in New Zealand in the early 1980's was first commenced this screening programme and was subsequently introduced nationally. In Malaysia there are few studies done in older students at year 5-6 of school (Md Daud *et al.,2009;* Director General Technichal Reports, 2007). The present study focuses on hearing screening among children at school entrance (year 1) using tympanometry, DPOAE and pure tone audiometry.

1.1.7 Delay detection of hearing impairment

Hearing loss is often not suspected by the parents or the pediatrician until language development is significantly delayed. Currently, in USA the average age of detection of significant hearing loss is about 14 months. In 1998 Yoshinaga-Itano *et al.*,confirmed that any intervention after the age of 6 months will most likely yield less than optimal speech and language development. Generally, the period between the first 6 months of life and 18 months has been widely postulated as the critical phase for this development (Yoshinaga-Itano *et al.*, 1998).

In 1984 Said H and Abdullah conducted the first study regarding hearing impairments in Malaysia, involving 38 school children attending classes for the hearing impaired, 75% of cases were identified as having hearing impairment after the age of one year and the remaining children were detected after 3 years of age.

In 1992 Maisarah *et al*., conducted the second study by involved children with sensorineural hearing loss attending ENT clinic of National University of Malaysia during the period extending from January to December 1990. Mostly of hearing impairment cases were confirmed at the age of 3 to 5 years and the residual were definite after 7 years of age whereas 25% of cases were established prior to the age of 2 years. However the conclusion of these studies recommended, in Malaysia, the hearing loss and its rehabilitation had been delayed and the significant of hearing loss in all infant must be recognized at age 3 months and obtain intervention at age of 6 months to avoid critical period in their development.

In 2007 the world health organization estimated that more than 4% of the world's population, i.e.287 million people has hearing loss, of this proportion, approximately two-thirds live in developing countries (McPherson *et al.,* 2010). The prevalence rate of hearing loss is thought to be high among school-aged children in developing countries. In developing countries the prevalence of hearing loss is thought to be high among school–aged children. In Swaziland a prevalence rate of 4.1% was noted (McPherson *et al.*,2010). Study showed that 5.6% of School children have mild hearing loss in Kenya, (Hatcher *et al.*, 1995).

Studies in South India (Rao *et al.,* 2002) have recorded higher prevalence rates 11.9% and in Nigeria 13.9% (Olusanya *et al.,* 2000). The prevalence rates in school children differ among developing countries due to differences in the way they conduct the study, sample, inclusion and exclusion criteria and other factors, hearing loss is more prevalent in the developing countries than in the developed (Berg *et al.,* 2006). In Finland the prevalence rate for hearing loss in school children was 2.5% (McPherson *et al.,* 2010) and in Denmark 3.6 % (Parving ,1999).

One per thousand is the estimated number of newborn babies with hearing impairment In USA. Many more are born with less severe degrees of hearing impairment while others develop hearing impairment during their life (Barsky-Firkser and Sun, 1997).

Study conducted in 1996 by Watson *et al.,* noted a prevalence of 1-2 per 1000 live births having significant permanent hearing loss of an averaging 50 dB in the speech frequencies. About 2 to 4 per 100 infants in the intensive care unit population and considerable bilateral hearing loss is present in about 1 to 3 per thousand newborn infants in the well baby population (Erenberg *et al*., 1999). Majority of the people live

in the developing world have hearing problems where there are limited resources and facilities for diagnosis and management of hearing problems(Al-Khamesy, 2002).

.In Beijing in August 1998 it was reported in the Asian Pacific Congress on deafness that in China, 24 million out of 1.2 billion people suffer from hearing problems. In Thailand there were 1.5 million children in school for the deaf; half of them are congenital hearing loss (Prasansuk *et al*., 2000).The prevalence rates for hearing impairment varied depending on age and criteria used in the test.

For severe hereditary and prelingually acquired losses, estimates range from 1 to 3/1,000 live births (Riko *et al.,* 1985; Ruben *et al.,* 1982 ;Morgan and Canalis, 1991).

1.1.8 Otoacoustic emission (OAE)

In normal ears, OAEs were found to be present, however they were absent in cases of deafness. For OAE to be an effective indicator of normal physiology, Kemp found that emissions occurred for the entire subject they tested with normal ear 100%. It is obvious that OAE has a high prevalence, but some of the researchers were not able to determine emissions in all normal subjects tested.

1.1.9 Clinical applications of OAE

The utility of otoacoustic emissions in clinical practice are mainly focused on the diagnosis of sensorineural hearing losses in the auditory periphery. The emissions existence gives us a direct evidence of the presence of cochlear active mechanism. OAEs have significant value in exploring the mechanical function of the outer hair cell. In a noninvasive and objective manner, OAEs achieved considerable clinical

importance and are going to be supplemented to other standard clinical methods in near future. This explains why measurement of OAEs in neonates and young infant is becoming widespread rapidly. OAE is used for screening of school children. There are some screening using OAE e.g. study done by Lyons *et al* (2004) investigated the performance of DPOAE screening relative to pure-tone testing and a battery combining pure-tone and tympanometry results in Australia and Krueger and Ferguson (2002) examined the test performance of DPOAEs relative to tympanometry and pure-tone audiometry in a sample of 300 children recruited from four schools in Texas, U.S.A.

1.1.10 Significance of the study

Mild hearing loss can affect the academic performance in primary school children, therefore if the prevalence is found to be high, the hearing screening is important to be done at the entry school age to detect hearing impairment as early as possible.

In hearing impairment the disability to hear is worsen by poor classroom acoustics. It is important to examine the acoustic environment in the classrooms and its designing compliance with the international standards.

1.1.11 Objectives and aim of the study

1.1.11.1 General objectives

To study the acoustic measurement of the classrooms and the status of hearing among children at entry school age.

1.1.11.2 Specific objective

1. To measure the sound attenuation levels in the locally made sound treated booth used in the study and compare the values with the imported sound treated booths in the audiology clinic.
2. To measure the levels of noise and reverberation times in classrooms of the selected schools.
3. To determine the failure rate of distortion product otoacoustic emission (DPOAE) among Year 1 school children.
4. To determine the middle ear function among Year 1 school children by using tympanometry.
5. To determine the prevalence of hearing loss and impairment among Year 1 school children by using pure tone audiometry (PTA).
6. To measure the sensitivity and specificity of DPOAE compared to PTA.

1.2 Literature review

1.2.1 Anatomy and physiology of the ear

The ear receives sound waves which are processed and transmitted to the hearing center in the brain for interpretation. The ear consist of three parts: the outer, the middle, and the inner ear (Woodson, 2001). The outer ear is the first point of contact between the individual and the sound. The outer ear composed of the auricle or pinna and external auditory canal. The auricle, or visible part of the ear, directs and concentrate the sound waves along the external ear canal to the tympanic membrane.

It consists of all the parts of the ear that lie lateral to the tympanic membrane (the eardrum) and includes the pinna and the auditory (ear) canal.

The pinna is composed mainly of cartilage and its function is to capture and funnel sound waves down the auditory canal to the middle ear. The auditory canal contains small hairs and glands that secrete wax and protect the ear from dust and insects. The posterior part of the auditory canal ends at the tympanum. When sound waves beat against the tympanum, it vibrates and transmits the sound waves to the middle ear.

The middle ear is a tiny, air-filled cavity between the bony wall of the inner ear and the eardrum.

It includes the tympanic membrane and a small air-space lying between the tympanic membrane and the bony wall of the inner ear. The middle ear contains the three smallest bones of the body, the ossicles, known as the malleus, incus and stapes. Two muscles in the middle ear, the stapedius and tensor tympani muscle are stimulated by loud sounds and have a role in protecting the cochlea from the damaging effects of noise. When the sound is steered into the middle ear, the tympanic membrane is set into motion by the

sound waves and begins to vibrate. This vibration then sets the ossicles into motion and sound is carried through the oval window into the inner ear. The eustachian tube opens into the middle ear and is also connected to the nasal cavity to ensure an equal degree of atmospheric pressure on both sides of the eardrum. This is necessary to preserve the eardrum's sensitivity to sound waves because if the atmospheric pressure differs, the eardrum loses some of its vibratory capacity.

The inner ear contains the organ for hearing known as the cochlea and sensory organ for balance (including the semi-circular canals). It is fluid filled and consists of the cochlea, utricle, the saccule and the semicircular canals. The cochlea, often referred to as the inner ear, is considered to be the main sensory organ for hearing, the other parts providing important information for balance.

The cochlea contains specialized hair cells which are sensitive to the vibrations sent from the middle ear. The vibrations initiate a wave complex in the cochlea fluid and displace the inner ear fluid and hair cells. The hair cells change the mechanical energy and the information it contains, into neuroelectrical signals, which are passed through the acoustic nerve to the brainstem and temporal lobe of the cerebral cortex, where the impulses are interpreted as sound.

The anatomy and physiology of the ear is mandatory to know by the school nurse in order for her to understand the results of hearing tests. Interpretations of the results of the hearing tests are often depend on the structure and function of the ear and its different parts. For the teacher to know the problem of a child with a hearing loss it will be much easier if the nurse will first explain the function of the ear, and then made it clear how the child's problem relates to the working of the ear (Yockel, 2002).

1.2.2 Development and process of hearing

Hearing involves the gathering and interpretation of sounds. Each part of the ear plays a role in translating sound waves from the environment into meaningful information to the brain (Schirmer, 2001). Research has shown that there are two general processes in hearing: (a) getting sounds to the brain through the outer, middle and inner ear; and (b) learning and interpreting the meaning of those sounds once they have reached the primary auditory receptive area in the temporal lobe (Flexer, 1995).

A research has indicated that newborns are more sensitive to sounds which come within the typical frequency range of a human voice, while being less sensitive to low-pitched sounds (Keenan and Evans, 2009). At birth the child hears poorly for the first few weeks, as a result of the external auditory canal not being completely free of detritus (remaining tissue) and the middle ear being largely full with a gelatinous tissue (Allen, 1992). However, after progressive resorption has taken place, the infant can soon hear normally. If the infant continues to be less sensitive to low pitched sounds and hears imperfectly, the hearing system is not well developed.

Flexer (1994) reports that when sounds are heard, an individual is actually interpreting a pattern of vibrations in the form of sound waves, which are air particles that originate from a source in the environment. After being set into motion by an energy source, the air particles collide resulting in the creation of repetitive waves. Sound has both physical and psychological characteristics. The physical dimensions of speech sounds include frequency, intensity and duration, while the psychological attributes of sound are pitch and loudness. Our capability to perceive sound is affected by the product of

the three physical dimensions. A hearing impairment will affect the perception of one or all of these features.

Frequency refers to the number of sound vibrations that occur in a single second (Schirmer, 2001). This phenomenon determines the pitch of a tone. The faster the vibration, the higher the pitch of the sound produced (Green, 1999). The frequency of a sound is measured in Hertz (Hz) and humans can hear frequencies ranging from 20 to 20, 000 Hz. However, the frequency range generally considered most significant for the perception of speech falls between 500 and 2000 Hz (Schirmer, 2001). This corresponds to the findings of Northern and Downs (2002) who report the output pitch range of human speech to be between 500 and 3500 Hz and close to the optimal frequency sensitivity of our hearing mechanism. From the above-mentioned findings it is clear that our hearing is designed to receive the most important element of communication, namely, speech.

Intensity refers to the pressure of a sound and is measured in decibels (dB) (Flexer, 1994; Schirmer, 2001). Research results indicate that the ear can respond to intensities between 0 and 100 dB (Schirmer, 2001). Speech sounds, however, range from about 20 to 55 dB. Duration refers to the overall length of time span of a sound and is critical to the sense and measurement of hearing.

All the sounds we hear are made up of a combination of basic pitches which give the sound its character: high pitches tend to make sounds ‘sharper’ while lower pitches tend to make sounds ‘fuller’ (Green, 1999). Sound varies in loudness and consequently the mechanisms of the ear have to cope with a variety of rapid changes in loudness when listening to conversation.

1.2.3 Hearing loss

Hearing loss in children is a silent and hidden disability because children are incapable to communicate that they have a hearing problem. The most serious sensory disabilities present in children is deafness because of its influence on the mental, emotional and social development of the affected person (Marschark, 1993). Hearing loss in children may go unnoticed for years because the children are incapable to tell anybody they have trouble in hearing; as a consequence. Many children missing out on auditory information during their formative years and are more common where the hearing loss is mild or fluctuating due to delay in identification of hearing loss (Bess, 1998). A great impact on a child's development in many areas including speech and language, social and education which are caused by undiagnosed hearing losses (Northern and Downs, 2002).

Hearing loss simply means one's decreased ability to hear sounds, and being a hearing-impaired individual does not mean that one is deaf! This is more of a terminology problem. When somebody said that you are deaf, it means that your hearing loss is in the severe-to-profound area. Someone with a hearing loss of less than these degrees of impairment is considered as a hard-of-hearing person (Umat *et al*., 2006).

Hearing loss is the most prevalent developmental abnormality present at birth is (White, 1997b).

As well as direct effects of deafness, mostly , those relating to hearing and speech, there are a variety of consequences of children's hearing loss that influence their interactions with the environment. It begins as a sensory problem, may become a perceptual problem, a communication problem, a speech problem, a cognitive problem,

a social problem, an emotional problem, an educational problem and ultimately a vocational problem (Haggard and Primus, 1999) .

The presumption that hearing loss can be reliably known based on a child's behavior in everyday situation has been shown to be faulty by a number of studies documenting outcomes from the use of parent questionnaires (Olusanya, 2001). Evidence suggest that for 9-year-olds with educationally significant hearing loss, up to 50% will have passed newborn hearing screening (Fortnum *et al.*, 2001). Finally, it is estimated that 9-10 per 1000 children will have identifiable permanent hearing loss in one or both ears by school-age (Shargorodsky *et al.*, 2010).

1.2 .3 (A) Etiology of hearing loss

In school age children there are numerous causes of hearing loss. For example, an obstruction in the ear canal, or fluid in the middle ear which are temporary and easily corrected and others causes are permanent and may only be corrected by hearing aids or other listening devices. When the mothers have infection during pregnancy, such as rubella, herpes may cause an infant's hearing loss at birth.

The detail etiology of hearing loss is discussed below in detail under the different types of hearing loss. The most common type of hearing loss in school age children is conductive hearing which can be corrected in most of cases either by medical or surgical.

1.2.3 (B) Types of hearing loss

There are three basic types of hearing loss; i) conductive, ii) sensorineural hearing loss and iii) mixed hearing loss.

1.2.3 (B) (i) Conductive hearing loss

"Conductive hearing loss, which is the most common loss in children, can be due to a problem in the external ear canal, tympanic membrane, or middle ear, obstructing the transmission of sound. Causes might be impacted earwax, foreign objects in the ear canal, otitis media, congenital abnormalities, and ruptured or scarred tympanic membrane secondary to trauma or infection. Conductive losses can be mild or more severe and are considered significant when they interfere with a child's ability to communicate in a proper way. Many cases of conductive loss can be treated with medical or surgical treatment. However, these losses may worsen over time so that a student who is referred to a physician for follow-up may not be having the loss at the time of medical check-up. Both types of hearing loss can occur at the same time. Person with a past history of irregular hearing loss might need urgent intervention to detect the need for medical treatment and to prevent permanent damage" (Niskar *et al.*, 2001).

"Conductive hearing loss by definition is the obstacle of sound to be conducted from the external ear to the inner ear. Patients with a conductive hearing loss have normally working inner ear. However, the signal is weakened, before it reaches the inner ear. Common causes of this type of hearing loss are otitis media (middle ear disease, such as

otitis media with effusion), impacted wax and ossicular discontinuity or injuries to the ear drum. Conductive hearing loss can be recognized if the air-bone gap is present" (Northern and Downs, 2002)

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1.2.3 (B) (ii) Sensorineural hearing loss

Loss of function of the inner ear (cochlear) or beyond the inner ear along the auditory pathways will lead to sensorineural hearing loss. Many causes of conductive hearing loss, like otitis media and ear wax, can be temporary while sensorineural hearing loss is usually permanent, (Northern and Downs, 2001 There are many causes of sensorineural hearing loss; nine common risk factors for infants are;

1. Positive family history of hearing loss
2. Low Apgar scores (0 to 4 one minute or 0 to 6 at five minutes)
3. Craniofacial abnormalities
4. Drugs that is toxic to the ear `
5. Prolonged mechanical ventilation for example five days and more
6. Jaundice requiring exchange transfusion
7. Low birth weight less than 1500 grams
8. Infections such as herpes, rubella and toxoplasmosis and those associated with hearing loss
9. Bacterial meningitis (Bird *et al*., 2007).

1.2.3 (B) (iii) Mixed hearing loss

In this type, elements of both sensorineural and conductive deafness are present. This occurs when both bone conduction and air conduction thresholds are abnormal but are significantly different (15dB apart) (Northern and Downs, 2002). This can occur when a child has a sensorineural hearing loss in conjunction with otitis media. Hearing loss is categorized by the severity of the loss and has differing effects depending on its severity. Normal hearing thresholds are approximately 20dB HL and below.

1.2.3.3 Degree of hearing loss

Degree of hearing loss refers to the severity of the loss. There are 5 categories that are typically used. The numerical values are based on the average of the hearing loss at three frequencies 500 Hz, 1000 Hz, and 2000 Hz in the better ear without amplification. There are many studies of hearing screening in schools with different frequency average e.g. 1000Hz, 2000 Hz, 4000 Hz (American guide line 2008) and Lyons *et al*., (2004). Krueger and Ferguson (2002) choose average of 500, 1000, 2000 and 4000Hz. In the present study the average of 4 frequencies 500Hz, 1000 Hz, 2000Hz, 4000Hz were chosen.

According to American school hearing screening guidelines in 2008, the degree of hearing loss is as follows (Ross *et al.*, 2008).

A. Mild hearing loss (21-40 dB)

B. Moderate hearing loss (41-59dB)

C. Severe hearing loss (60 to 85 dB)

D. Profound hearing loss (85dB or more)

According to Australian hearing 2005 the degree of hearing loss is as follows

A. Mild: 21-45 dB

B. Moderate: 46-65 dB

C. Severe: 66-90 dB

D. Profound: 91 dB + (Australian hearing 2005).

Degree of hearing loss accordingly to the WHO classification;

The degree of hearing loss is almost always important when discussing the effects of hearing loss on child development. A broad variety of definitions and classifications are still in use today (Duijvestijn *et al.*, 1999).

WHO classified degree of hearing loss as

1- Normal, no impairment = 0 - 25 dB (better ear).

2- Mild impairment = 26- 40 dB.

3- Moderate impairment = 41- 60 dB.

4- Severe impairment = 61- 80 dB.

5- Profound impairment = 81 dB or greater (WHO., 1991).

Hearing impairment is usually described by measures of hearing, such as loss of sensitivity and loss of acuity. It can be measured rather precisely, with results reported

in dB or percentage loss of discrimination. When defined medically, hearing loss is categorized at levels from slight to profound. The problem with these definitions, however, is that the words can give a false impression of the level of difficulty the child may face. The disabling effects of a given impairment are not so easily ascertained. Using medical definitions of hearing loss, Batshaw and Perret (1981) distinguished hearing loss as follows: children with light hearing loss (25-45 dB), moderate hearing loss (45-70 dB), and profound hearing loss (90 dB). Davis and Hardick (1981) stated that hearing loss can be expressed precisely in terms of decibels, speech discrimination scorers, speech reception threshold or pressure in the middle ear.

1.2.3.4 Mild and minimal hearing loss in school age

Absence of the physical symptoms and findings in the children with mild hearing loss for sure will make it too difficult to identify those children, without the school hearing screening program but, behavior problems like inattentiveness, asking to repeat the question frequently, responses inappropriate to instructions and confusion of similar sounding words may high light hearing loss. In addition to that, a child with mild hearing loss may talk loudly or softly, act out in class, or his speech is distorted (Md Daud *et al.,*2009). Nevertheless, the behavior symptoms are subjective and usually being ignored by teachers and parents. Mild hearing loss in certain kids might affect their studies causing poor results.

Even the minimal hearing loss which is defined as a hearing loss ranging from 16 dB - 25 dB by most authors will affect the academic achievement (Flexer, 1995).

Over the last two decades the prevalence of children with severe to profound hearing loss seems to have declined while milder forms of hearing loss seems to be increasing (Tharpe and Bess, 1991). In a general school population the prevalence of mild hearing loss has been estimated at close to 11.3% (Bess *et al.*, 1998). Depending on the area of study and the cutoff point taken to indicate hearing impairment, the prevalence of hearing loss among school children were ranging from 2.4 to 14.9% (Niskar *et al.*, 2001; Olusanya *et al.*, 2000; Westerberg *et al.*, 2005 ; Rao *et al.*, 2002).

Moderate to profound hearing loss will cause serious impact on the child's development. However, a mild degree hearing loss may cause hearing problems. It might not seem important since this group of children can hear all but a soft whispering in quiet environment (Crandell and Smaldino, 2000) . Nevertheless, Bess *et al.*, (1993) have reported that the group had significantly poorer performance relative to normal hearing peers on basic skill tests. Undiagnosed mild hearing loss in certain kids might affect their studies causing poor results.

1.2.3.5 Economic impact of hearing loss

One of the accepted principles of screening is that economically balanced in relation to possible expenditures of resources. Disorders of hearing, speech, voice and language and the costs of special education, underemployment and unemployment and rehabilitation resulting from these disorders are thought to be approximately 3% of the national gross production of the USA in 1999 (Ruben, 2000).

Data from a lot of surveys was analyzed by the RTI International (Research Triangle Park, North Carolina) and the centers for disease and prevention (CDC) and the result