CHAPTER 1

INTRODUCTION

1.1 GENERAL

Sound we would choose not to hear if we had the choice is called noise. The word ‘noise’ comes from the Latin word ‘nausea’ meaning seasickness. Noise has always been an important environmental problem for man. In ancient Rome, rules existed as to the noise emitted from the ironed wheels of wagons which battered the stones on the pavement, causing disruption of sleep and annoyance to the Romans. In Medieval Europe, horse carriages and horseback riding were not allowed during night time in certain cities to ensure a peaceful sleep for the inhabitants (Berglund et al 1995).

However, the noise problems of the past are incomparable with those of modern society. Modern roadways (including road, rail, and air) and the products of modern technology produce increasing levels of unwanted noise of varying types and intensities throughout the day and night that disturb sleep, concentration, and other functions (Lee and Fleming 2002, Ising and Kruppa 2004, Bluhm et al 2004, Carlos 1999). Aircraft and trains add to the environmental noise scenario. In industry, machinery emits high noise levels and amusement centres and pleasure vehicles distract leisure time relaxation. This noise affects us without our being consciously aware of it. Unlike our eyes, which we can shut to exclude unwanted visual input, we cannot voluntarily shut our ears to exclude unwanted auditory input. Our
hearing mechanisms are always “on” even when we are asleep (Goines and Hagler 2007).

1.2 EFFECTS OF EXCESSIVE NOISE

Noise pollution is an unwanted human-created sound that disrupts the environment. In spite of the attempts to regulate the noise pollution, it has become an unfortunate fact of life worldwide (Goines and Hagler 2007). There is growing evidence that noise pollution is not merely an annoyance; like other forms of pollution, it has wide-ranging effects on health, social, and economic effects (Evans and Lepore 1993). As the population grows and as sources of noise become more numerous and more powerful, there is increasing exposure to noise pollution, which has profound public health implications. Noise, even at levels that are not harmful to hearing, is perceived subconsciously as a danger signal, even during sleep (Babisch et al 2005). The effects of noise pollution on cognitive task performance have been well-studied. Noise pollution impairs task performance at school and at work, increases errors, and decreases motivation. Reading attention, problem solving, and memory are most strongly affected by noise. Two types of memory deficits have been identified under experimental conditions: recall of subject content and recall of incidental details. Both are adversely influenced by noise. Deficits in performance can lead to errors and accidents, both of which have health and economic consequences (Berglund et al 1995).

1.3 EFFECT OF NOISE ON CHILDREN

Excessive noise can interfere with learning by affecting memory (Hygge 2003) and acting as a distraction that impairs a student’s ability to pay attention. The ability to pay attention is most important when students are engaged in tasks that demand higher mental processes, such as learning new
concepts, or when teachers are presenting new or complex information (Hartman 1946).

Excessive background noise in a classroom can come from outside the building (aircraft and traffic noise, lawn mowers and other equipment, or students engaging in sports activities) or from within it (heating, ventilation, air conditioning, plumbing systems, adjacent classrooms, hallways, gymnasiums, or music rooms) or from the students themselves. The level of residual noise from the students may be dominant, but is strongly related to the ambient noise in the room. That is, student chatter will increase as the general level of ambient noise increases, an example of the Lombard effect (Junqua 1996). Thus, it is important to minimize all other sources of noise to ensure lower levels of student noise. It is equally important to educate teachers about the effects of noise on speech communication. As adults, teachers may not appreciate the additional problems that noise creates for younger listeners.

Although the importance of classroom acoustics to educational outcomes is well supported in the research literature, it is frequently ignored by school officials and by those designing schools. Anderson (2004) suggests there are at least four reasons for this:

First, administrators walk into classrooms, listen briefly with adult ears and do not recognize that auditory immaturity causes young children to experience greater listening problems and less coping ability than the mature auditory systems of adults. Second, most school administrators have not been exposed to the extensive body of research that illustrates the effects of excessive background noise and/or reverberation on students’ listening, learning, and behavior. Third, administrators often believe that good classroom acoustics are only needed for children with hearing impairment and those children with hearing loss and auditory learning difficulties comprise
only a very small proportion of the children educated in inclusive classroom settings. Fourth, school administrators are typically unaware of the health issues faced by teachers who instruct in noisy classrooms and the expense that this may cost the school district.

1.4 EFFECT OF NOISE ON TEACHER

In addition to children’s hearing concerns, the effect of trying to compete with an acoustically difficult environment creates a problem of severe strain on the vocal chords for many teachers. Classroom noise has also been shown to affect teacher performance (Crook and Langdon 1974, Ko 1979, Sargent et al 1980). Ko (1979) obtained information from more than 1,200 teachers concerning the effects of noise in the classroom. Results indicated that noise related to classroom activities and traffic or airplane noise were correlated with teacher fatigue, increased tension and discomfort, and an interference with teaching and speech recognition. Additional studies (Crandell and Smaldino 1995, Sapienza et al 1999) reported that teachers exhibit a significantly higher incidence of vocal problems than do the general population. According to US National Center for Education statistics, teacher’s on an average take leave for 2 days/year for vocal fatigue caused by raising their voices to talk over noise and the cost for substitute teachers was an additional expense. It is reasonable to assume that these vocal difficulties are caused, at least in part, by having to increase vocal output to overcome the effects of classroom noise during the school day.

1.5 UNDERSTANDING SOUND

In a classroom the sound level consists of background noise in the class, the external noise and its intrusion, student generated noise and the noise from the equipment such as fan, computer if any etc. These are to be measured and considered for assessing the acoustic environment in the class.
1.5.1 Perception of Sound

Before considering acoustics in classrooms it is helpful to understand what is normal for a classroom ‘full of students’ (Figure 1.1). Sounds are transmitted by pressure waves moving through the air. In a classroom full of students, sound in the form of noise is heard inside the classroom, outside the classroom and various other phenomena like reverberation and café effect occur naturally inside the classroom. Sound pressure levels give an indication of the level of sound. The sound levels can be measured by a sound level meter and are expressed as ‘decibels’(dB). The sound range of human hearing extends from about 16 dB, which is at the threshold of human hearing, to 140 dB, which is above the threshold of pain. In general, the pressure level decreases as the distance from the source increases. Table 1.1 shows typical sound levels in a school.

<table>
<thead>
<tr>
<th>dB</th>
<th>Source and Distance where applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Threshold of human hearing (person with good hearing)</td>
</tr>
<tr>
<td>20</td>
<td>Quiet recording room</td>
</tr>
<tr>
<td>35-40</td>
<td>Quiet unoccupied class room</td>
</tr>
<tr>
<td>60-70</td>
<td>Busy classroom-lots of students</td>
</tr>
<tr>
<td></td>
<td>Normal voice at 1 meter</td>
</tr>
<tr>
<td>80-90</td>
<td>Vacuum cleaner</td>
</tr>
<tr>
<td></td>
<td>Person shouting at 1 meter</td>
</tr>
<tr>
<td>100</td>
<td>Very loud disco music(maximum recommended by World Health Organization)</td>
</tr>
</tbody>
</table>
1.5.2 Noise from inside

The natural level of internal noise present inside a classroom is called the background noise or the ambient noise. Background noise refers to any auditory stimuli that interfere with what a child wants or needs to hear and understand (Crandell and Smaldino 1995).

1.5.2.1 Background (ambient) noise

The natural level of noise in a classroom when it is occupied is called the ambient noise level. Some sources of internal noise are shown in Figure 1.2. High levels of ambient noise significantly reduce a student’s ability to concentrate, and speaking over it can be stressful on the teacher. Many sources contribute to the background noise (BN) level of a classroom, including noise:

- generated outside the school property (transportation and building construction)
- generated within the school property (maintenance work and from the playing fields)
• transferred from nearby classrooms, corridors and noisy areas (music and technology rooms)

• created within the classroom (computers and fans).

• generated by students within the classroom – talking, rubbing of shoes, opening and closing of pencil box, turning of the pages of a book.

• an additional source of noise which is reputed to cause significant disturbance to teaching is the noise of rain falling on lightweight school roofs (O’Neill 2002).

Background noise from within the classroom is often more subtle than loud external noise and can also contribute significantly to poor acoustics. Noise created by fans, computers, printers and other equipment is often not noticed by adults because of their skills in selective listening. However, such noises may be distracting for students.

![Figure 1.2 Some sources of Internal Noise](image)
1.5.3 Noise from outside

As classroom windows provide ventilation, outside noise, which intrude into the classroom through the windows contributes to high noise in classroom. Possible intrusive noises from the outside are shown in Figure 1.3. Air–craft noise, road traffic noise and people shouting are some of the main sources of external noise intruding through openings. Teachers have indicated that the greatest outside noise is from their sports fields and other classrooms. The predominant external noise source, particularly in urban areas, is likely to be road traffic (Dockrell and Shield 2002) although aircraft noise may also affect many schools. Only fewer schools are exposed to railway noise. However, improving acoustics to help minimise outside noise cannot be seen in isolation from the impact on other important aspects such as ventilation and air quality.

Figure 1.3 Intrusive noises from the external sources
1.5.4 Reverberation Time (RT)

Sounds bounce off hard surfaces, such as painted walls and vinyl floors, so that listeners hear several indistinct, overlapping versions, which smear the original sound. The sound continues for a time, reflecting around after it has stopped at its source. This is called ‘reverberation’. The length of time the echoes take to reduce by 60 dB is called the ‘Reverberation Time’. If the reverberation time is too long the extended reflected sounds mask or blur the direct sound, which makes it hard to understand what someone is saying. Some reflected sound is good for understanding what someone is saying because it may reinforce their voice, but it’s a matter of careful balance. Reverberation times are measured in seconds, and typical ideal times range between 0.3 seconds for a recording studio and 2.0 seconds for a performing music hall.

Speech perception studies have investigated how interference from noise and reverberation influences the recognition of syllables, words, or sentences in classrooms. Kindergarten and first and second grades are the main years during which children learn to break written words into their phonetic components and acquire the ability to read. Careful listening is needed to develop the ability to discriminate among minor differences in words such as pet, pit, pot, put, and pat (Anderson 2004). Such differences can be lost in a noisy environment, so young children require the higher signal-to-noise ratios provided by quieter conditions. The impacts of excessive noise vary according to the age of the students, because the ability to focus on speech is a developmental skill that evolves and does not mature until ages 13 to 15 years. As children mature they tend to develop strategies to cope with noise levels. Accordingly, young children require better acoustical environments than do adult listeners to achieve equivalent word recognition scores (Elliott 1979). Classrooms of younger children are also found to be
noisier (Picard and Bradley 2001). A student’s difficulty in understanding speech in noisy situations may not be recognized by teachers, building designers, or other adults. That is, adults cannot rely on their own perception of speech under adverse listening conditions to recognize a child’s difficulty under the same conditions. Elliott et al. (1979a) found that the ability to recognize sentences in noisy environments improves systematically with age for children who are 5 to 10 years old. Similar effects of children’s age on speech perception in noisy environments were reported by Finitzo Hieber and Tillman (1978) and Marshall (1987). Especially for children studying in a language other than the mother tongue the noise problems in class would enhance the difficulty in understanding all words. Several studies have been done to emphasize that if the early arrival or early reflections of teacher’s voice reach the students sufficiently early, they enforce the speech intelligibility, before the reverberation starts masking the clarity of speech. It is established by Sato and Bradley (2008) that early arriving reflections of speech sounds reaching the listener within 50 ms after the arrival of direct sound are useful because they can help to increase the effective signal to noise ratio and hence the intelligibility of the speech. A room with very short reverberation time will be lacking in early reflection energy at positions farther from the teacher where the early reflections energy would be most helpful to add to the weaker direct speech sound.

1.6 CLASSROOM ACOUSTICS

Careful attention to acoustical design requirements, then, is essential for creating an effective learning environment. Nonetheless, a 1995 report of the U.S. General Accounting Office estimated that the acoustical quality in approximately 22,000 U.S. schools attended by 11 million students was unsatisfactory (GAO 1995). Excessive noise and reverberation interfere with Speech Intelligibility, resulting in reduced understanding and therefore
reduced learning. In a report in 1995 (GAO 1995) it was stated that in many classrooms in the United States, the speech intelligibility rating is 75 percent or less. That means that, in speech intelligibility tests, listeners with normal hearing can understand only 75 percent of the words read from a list. Imagine reading a textbook with every fourth word missing, and being expected to understand the material and be tested on it.

One way to describe the desired acoustical quality in a classroom is to specify an acceptable maximum ambient noise level. This level is measured in terms of A-weighted sound levels or octave band sound levels that can be used to determine other measures such as noise criterion (NC). By combining the effects of sound at different frequencies in a manner similar to that which takes place in the human hearing system, these measures rate the loudness of sound to listeners. A second way to describe acceptable room acoustical quality is to specify the reverberation time. Reverberation time (RT) increases with room volume and decreases as sound-absorbing material is added to a room. However, excessive sound-absorbing treatments will have the negative effect of reducing speech levels and degrading the intelligibility of speech in a classroom. People’s ability to understand speech is influenced largely by how loud speech sounds are relative to ambient noise or any other competing sounds. Reverberant sound causes one word to smear into the next and can decrease the intelligibility of speech. Acoustical design should be aimed at improving the recognition of speech sounds in the classroom. The focus should be first on reducing unwanted noise and then on controlling excessive reverberation. Good acoustical design can facilitate learning by allowing a more accurate verbal interaction and less repetition among teachers and students because spoken words are clearly understood. There is also evidence that good acoustical design may have an effect on health of the teacher, by reducing the potential for vocal impairment, and it may have the ancillary benefit of reducing teacher absenteeism. Teachers who work in noisy
classrooms must constantly raise their voices to be heard over other sounds. Over time, speaking in noisy environments can lead to vocal fatigue and other voice problems. Voice problems occurred more frequently for teachers of the lowest grades, those in larger classrooms, those with more students, and those in classrooms with higher noise levels. It was found that while 20 percent of the teachers had missed work owing to voice problems, only 4 percent of other professionals (non-teachers) had done so.

1.6.1 Signal-to-Noise Ratio

Signal-to-noise ratio (S/N ratio), which is really the difference between the sound level of signal and the background noise and also referred as signal-to-noise level difference (SNA). This is of pre-eminent importance for communication in any space since in the absence of an adequate S/N ratio all other design efforts become irrelevant. In a classroom the ‘signal’ is generally the teacher’s voice (in a group work situation it is the other students communicating in the group) and the ‘noise’ is the sound from all other sources. S/N ratio will vary depending on a student’s position in the room and the activity taking place but there is a minimum value which should be maintained in order to ensure optimum speech intelligibility. For young children of normal hearing S/N ratio should be about +15dBA (Bradley 2007) for more than 90 % recognition of words. S/N Ratio, RT and percentage of words recognised by the students are interconnected; if RT is low (less than 0.6s) the S/N ratio of +15dB would result in more than 90 % word recognition for elementary school children (Shield and Dockrell 2003).

1.6.2 Speech Intelligibility in Classrooms

Speech Intelligibility (SI), which quantifies the quality of verbal communication, is a major concern regarding the acoustical characteristics of
classrooms. SI is the percentage of speech material presented to an average listener which is correctly transmitted from a speaker to a listener (Hodgson 2001). Non-optimal classroom design, acoustical conditions and SI can result in impaired verbal communication between a teacher and a student, with detrimental effects on learning causing two main problems:

1. Reduced learning efficiency,

2. Can lead to fatigue, stress and health problems (headaches and sore throats) among lecturers, who are forced to compensate for poor acoustical conditions, by raising their voices. Both Bradley (1986) and Hodgson (2002) have carried out experimental and theoretical studies to investigate the relationship between background-noise, Reverberation Time and Speech Intelligibility in the classroom. A general conclusion of these studies is that background- noise is the more critical factor and that criteria for acoustical conditions in the classroom should be based upon Speech Intelligibility. The acoustical design of classrooms should be based on achieving the highest possible degree of Speech Intelligibility for all listeners in the room (EN 2003).

1.7 NEED FOR RESEARCH

Despite the existence of guidelines for school and classroom noise, and a body of research on the effects of noise on children and teachers in the classroom, there is relatively less information on noise levels outside the classrooms and its influence within the classrooms (Dockrell and Shield 2002). The acoustics of school classrooms in India are also influenced by climatic factors. In a warm-humid climate, where air-conditioning and tightly closed enclosures for the classrooms are not in practice the noise inside classrooms is highly influenced by the external noise. In a developing country
like India where energy conservation is considered important and ventilation is a prime factor to be considered, the windows and doors are kept open. In India schools are of varied nature -- government schools, partly government and private schools with no specific locations or model plans -- depending on the particular education administrators, availability of land and other factors. The government-run schools provide free education. Private schools are built, depending on the economic status of the administrators. In many of the classrooms fans are provided to supplement the natural ventilation. There would be only a very small percentage of schools with air-conditioning or heating, which are made to international standards.

The Speech Intelligibility is influenced by the background-noise, Reverberation Time and the distance from the source to the listener. In the classrooms of the warm-humid climate regions the possibility of increased background noise in the classrooms due to the intrusion of noise through the open windows and doors along with the noise from fans remains higher than that in the enclosed classrooms. As the background noise is a fundamental parameter for determining the intelligibility in classrooms, the assessment of speech intelligibility in such classrooms becomes necessary. One must assess how far the typical Indian classrooms satisfy the requirement of better learning environment for school children.

1.8 SCOPE AND OBJECTIVES

The scope of the thesis was to investigate the acoustics in Indian school classrooms and to assess how far a good learning environment for the young children prevails in the classrooms. With the real conditions of Indian classrooms to evaluate how does the Speech Intelligibility within the classroom compares with the other national and International standards becomes necessary. This being the scope, following are kept as objectives.
1.8.1 Objectives

The objective of the study was to assess the influence of external noise on the background-noise in the classrooms, in tropical climates where the windows and doors are kept open during class sessions and to examine the influence of external noise on the learning environment of the children in schools, by measuring the sound levels within the classrooms, and outside the classrooms. The details are:

i. To measure the noise outside the classrooms, within the school compound and at the source of the noise to assess the influence of external noise on the background noise of the empty (unoccupied) classroom and when the classroom is in session.

ii. To measure the Reverberation Time in classrooms in occupied and unoccupied conditions and to compute the Reverberation Time in the Classrooms using a computer software and to compare the values with measured and computed values.

iii. To compute the parameters of Speech Intelligibility in the classrooms and to carry out a parametric study on the influence of RT and BN on Speech Intelligibility.

iv. To improve the Speech Intelligibility by implementing simple additions in the classrooms and to verify with measurement and calculation.

v. To suggest the means to improve the acoustic performance of classrooms by proper zoning and location.
1.8.2 Study Area

The schools evaluated are from an educationally advanced town Nagercoil located in the southern part of India, in the Kanyakumari District, which is one of the 32 districts in the state of Tamilnadu, having 808 schools out of which 522 are primary and middle schools with about 190,000 students (Education 2010). The locations of the schools in relation to noise sources vary; some are adjacent to busy roads, others are set back from the road, separated from the roadside by playgrounds; many are located away from main roads, on side streets. It was therefore necessary to survey schools subject to a wide range of noise levels. Some schools located close to main roads or industrial areas are subjected to high levels of noise, whereas some schools are sheltered from road traffic noise by surrounding residential buildings, and others are located in remote areas of the town. Hence the study area was classified under three categories as:

1. Schools located near public roads (Noisy-sites);
2. Schools located in Housing sites;
3. Schools located in Quiet sites.

The schools under survey were generally low-rise buildings, either single- or double-storied, a few three-storied. The classrooms have 230-mm brick walls with plastered surfaces. The floors are cement plastered surfaces without any covering with carpet and the ceiling is concrete covered with cement plaster. The area under study was away from flight paths of aircraft, and from rail traffic.

1.8.3 Methodology

A total of 120 classrooms in 25 schools in the three sites were studied. The surveyed schools were attended by children from the 1st to the 8th grades (6-14 years old) of the fundamental educational system, which
corresponds to primary and middle schools. Internal and external noise surveys were carried out around the schools to provide information on typical sound levels and sources to which children are exposed while at school. Many of the schools surveyed were exposed to noise from road traffic; the average external noise level was measured outside each school. Detailed internal noise surveys were carried out in the classrooms together with classroom observations to verify the acoustical conditions of the classrooms for the development of teaching learning process. External noise levels were compared with internal levels to determine the influence of external noise on the internal noise environment of the classrooms.

Reverberation time was measured in the classrooms when the classrooms were empty and when they were occupied by the students. The software ClassTalk was used to calculate also the RT in the classrooms. The speech intelligibility parameters like Signal to noise ratio, Speech Intelligibility and Speech Transmission Index (STI) at different locations in the classrooms were computed and discussed. The means to improve the speech intelligibility are also discussed and presented.

1.9. ORGANISATION OF THESIS

Chapter-1 Introduction

This chapter discusses the importance of acoustic environment in school classrooms for children and discusses the need for this study along with the Objectives of the study.

Chapter-2 Literature review

In this Chapter the present status of knowledge on BN, RT, SI, STI, as available in Published literature is presented. A critical review identifying
the gap in the research in order to substantiate the need for the present research is discussed.

Chapter-3 Classroom Noise

In this chapter the sound levels in 120 school classrooms in the study area were measured presented and compared with the external noise. The background-noise in the classrooms is compared with the different national and international standards. The RT in the classrooms in different conditions were also measured and discussed.

Chapter-4 Reverberation

The Reverberation times in the classrooms were measured and also calculated using software ClassTalk. The measured and computed values were compared.

Chapter-5 Speech Intelligibility

Detailed calculations of Speech Intelligibility parameters in classrooms were carried out and the influence of the parameters presented and discussed.

Chapter-6 Methods to achieve better learning environment

Measures to improve the Speech Intelligibility were attempted in a few classrooms and the effects were measured, computed and discussed.

Chapter-7 Summary and Conclusions

In this chapter the summary and conclusions are presented indicating the scope for future studies.