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# Intermittent noise sampling and control strategies in the hospital environment

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## **ABSTRACT**

### **NOISE SAMPLING AND CONTROL STRATEGIES IN THE HOSPITAL ENVIRONMENT**

**by**  
**Rosarito M. Guerrero**

Noise in the hospital environment can have negative effects on both patients and hospital staff. Unwanted noise can be disturbing and often annoying thus, interfering with patients' sleep and obstructing work performance of the hospital staff. A research study was conducted in the hospital unit to identify and develop methods of intervention for intermittent noise and their source. Routine staff work activity generated noise levels above EPA hospital noise recommendations. A sound level meter and video camera was used to capture noise between the work-shifts. The video camera captured digital readings generated by the sound level meter which, helped identify high intermittent noise and approximate hour it occurred within that day.

Statistical analysis shows that noise levels varied among different days of the week. An analysis of variance and a multiple range test was performed and results indicated that there were different noise levels among the sampled days. Routine staff work activity and conversation among other staff members are the major cause of noise peaks. A personal interview with one staff member briefly discussed the main source of hospital noise to be interaction among other staff members in addition to daily use of hospital equipment and handling other hospital supplies. A possible intervention to noise control in the hospital unit is staff awareness and education. In addition, modifying an existing equipment or purchasing new equipment with noise specification options will help decrease and/or eliminate noise.

**INTERMITTENT NOISE SAMPLING AND CONTROL STRATEGIES  
IN THE HOSPITAL ENVIRONMENT**

**by  
Rosarito M. Guerrero**

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**August 2001**

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## **CHAPTER 1**

### **INTRODUCTION**

Noise within the hospital environment is becoming more recognized. Health care organizations are expressing more concern for the well being of their patients. Health care organizations are also more cognizant of the hospital staff's work environment and are attempting to be more effective in meeting the needs of their patients. A significant concern that is becoming noticed, is the generation of noise in hospitals particularly, intensive care units.

Various sources such as, hospital equipment, monitor alarms, and phones, all of which can affect a patient's rest and recovery, may cause the increase in hospital noise level. Previous research studies on noise stress the importance of patient satisfaction during length of stay in the hospitals. Interventions such as, implementation of a noise abatement program and education of hospital staff are just a few programs that have been created to reduce noise and increase the overall patients' satisfaction.

The purpose of this study is to evaluate and identify the possible noise sources produced in the hospital environment that contribute to the disturbance of patients' sleep and recovery. A noise source was identified according to the peak sound level that exceeded 60 dBA. The largest and most active unit was selected for the study. Data points were collected and analyzed for peak and intermittent high levels of noise. The level of noise varied from each work shift but the noise source captured remained consistent throughout each of the days observed. Whether noise resulted from equipment, patients, or hospital staff, it remained similar throughout each day's activity.

In summary, the objective of the study is to (1) identify the noise that is equal to and greater than 60 decibels (2) compare, analyze and interpret the results of data obtained from each of the 8-hour tapes, (3) discuss the results and overall conclusions of the study, (4) develop recommendations for improvement, which can decrease and/or eliminate the high level noise source and (5) communicate results in order to help increase the awareness of nurses and other hospital staff working in this unit.

The chapters included in the study will provide an overall introduction to the definition of noise, some of its effects, methods used in obtaining and analyzing the data, and discussion of results and recommendations. The following literature review introduces the physical properties of sound and discusses some of the psychological and physiological effects of noise on hospital patients, nurses and staff. The review continues to elaborate on the annoyance of noise and how patients of different age groups and gender perceive and respond to noise.

Several studies previously conducted were compared to hospital noise regulations and determination was made on whether different size hospitals were in compliance with the recommended EPA hospital noise level standards. Other relevant topics included in the literature review are the three classes of noise, sleep disturbance due to noise, and noise comparison in small and large area hospitals. Chapter 3 and the subsequent chapters present information on research methods and findings. It will cover aspects of the study in terms of equipment used, method of data collection, statistical analysis, conclusion, recommendations for improvement and a final discussion.

## **CHAPTER 2**

### **LITERATURE REVIEW**

In spite of technological advances, noise levels in hospitals have increased to an extent that they are potentially harmful to both patients and personnel (Kam and Thompson, 1994). Noise may be defined as any unwanted or undesirable sound, which is subjectively annoying or disrupts performance and is physiologically and psychologically stressful (Kam and Thompson, 1994). Hospital noise may be influenced by several factors that can lead to the disturbance of patients' sleep (Haddock, 1994). Hospital noise includes loudness of conversation, paging systems, alarms from monitors, or even housekeeping equipment. They also include patient noises, such as coughing and snoring; staff noise and environmental noises caused by telephones or objects and doors banging (Haddock, 1994). Certain departments within the hospital environment are likely to generate more noise when compared to others due to the difference in equipment and amount of interaction present between the hospital staff and patients.

#### **2.1 Physical Properties of Sound**

Sound is produced by a change in air pressure (water or other medium), which can vary over a period of time (Plog, Niland and Quinlan, 1996). Sound refers to the form of energy that produces a sensation detected by the human ear (Plog, Niland and Quinlan, 1996). The level of sound is measured in decibels (dB) and the pressure changes that produce sound is frequency, measured in hertz (Hz). Frequency is recognized as a pitch. A high or low pitch sound is identified on a frequency spectrum based on the number of sound wave cycles that occur.

Noise is unwanted sound that can be characterized from the frequency spectrum as either high or low frequency. High frequency noise is more hazardous and is typically annoying compared to low frequency noise. A long - term high frequency noise exposure is also damaging and more harmful than low frequency noise. The human ear is capable of perceiving sounds within a frequency range of 20-20,000 Hz, and most sounds that occur in every day life are between 60 – 60,000 Hz (Kam and Thompson, 1994).

Also attributed to the concept of noise is intensity, loudness of sound. The amplitude of the sound wave determines intensity on the frequency spectrum. Although loudness depends primarily on sound pressure, it is also affected by frequency. Overall, the characteristic of sound involves the frequency spectrum and sound pressure level over a period of time.

Unpleasant or unwanted sound is noise. The frequency spectrum can determine the level of annoyance caused by noise; high frequency noise is generally more annoying than low frequency and narrow frequency bands or pure tones can be more harmful to hearing than broadband noise (Plog, Niland and Quinlan, 1996). When individuals are exposed to unwanted noise in the environment it can often be disturbing and even detrimental. In most instances noise can have several effects, which can alter a person's cognitive thinking, physiological actions (task specific), and level of stress.

## **2.1 Psychological and Physiological Effects of Noise**

The hospital environment has been a subject of study for many years and in 1860, Florence Nightingale identified unnecessary noise as a disturbance that creates an expectation in the mind that which hurts a patient (Griffin, 1992). Patients confined to

stay in the hospital environment are exposed to various sources of noise. They are exposed to sounds of varying intensity, duration, and frequency most of which are perceived as disruptive and frustrating because they cannot eliminate the source of sound (Griffin, 1992). The hospital staff is frequently exposed to the same type of noise day after day and become accustomed to the sounds produced in their environment. They may either be unaware or just overlook noise that otherwise may continuously disrupt the patients.

Response to noise varies among individuals and can lead them to react differently. Unwanted noise can often be annoying. Annoyance is a psychological response to noise, and signifies one's reactions to the sound based both on its physical nature and its emotional content (Griffin, 1992). Noises that are described as annoying are high pitch, intermittent, of long duration, impulse in character, greater than 60 dBA, and increasing in level (Griffin, 1992). An individual's hearing will adapt to a continuous noise, such as the hum of machines, but will be disrupted by intermittent noises, such as laughter or a telephone ringing (Griffin, 1992). Exposure to moderate levels of noise can lead to psychological stress which includes feeling of bother, interference with activity and even symptoms such as headaches, tiredness and irritability (Kam and Thompson, 1994).

Noise can either be continuous, intermittent or vary in intensity and frequency. Individuals are most commonly affected by peak or sudden noises as opposed to continuous noise. Sudden and unexpected noise can cause a startle reaction, which may provoke physiological stress (Kam and Thompson, 1994). When the body is startled, a complex physiological reaction is initiated which includes pupil dilation, increased vasoconstriction and blood pressure elevation (Biley, 1994). These physiological



changes can ultimately have significant negative effects on the physical well being of patients and act as a contributing factor to delayed wound healing (Biley, 1994).

Noise does not only affect patients' sleep and recovery but also contributes to a decline in work performance. In general, noise increases arousal and may impair complex intellectual functions and performance of complex tasks, especially reducing accuracy and the capacity to respond to the unexpected (Kam and Thompson, 1994). According to Carol F. Baker (1993), Assistant Professor of Ohio State University College of Nursing, noise affected task performance by increasing arousal and focusing attention on dominant features of a task, thus interfering with subsidiary tasks. She also stated that noise helped concentration on a simple task but was damaging to performance of intellectual tasks such as reading, writing, and calculating (Baker, 1993).

Heart rate response is also a main concern for patients when exposed to environmental noise. When exposed to noise, the patient may experience discomfort, which can lead to physiological and psychological responses. Discomfort occurs when environmental demands placed on an individual exceed the person's ability to cope (Baker, 1992). Noise in the Intensive Care Unit (ICU) has previously been documented as a problem for patients and depending on the occupancy of a unit, noise levels may range from 45-90 decibels over a 24-hour period (Baker, 1992). Baker (1992) further states that since ICU patients are often isolated and unfamiliar with their surroundings, they have little control over their immediate environment and may be more susceptible to excessive multiple environmental stimuli. There are several effects that a critically ill person may encounter. Baker (1992) includes cardiovascular arousal, sleep deprivation, and ICU psychosis with delusions and hallucinations. These effects have only been

studied in Surgical Intensive Care Units. Marshall, Storlie, and Conn (1981) have reported that cardiovascular arousal has not been studied in a non-cardiac Surgical Intensive Care Unit population and nor has a method been developed for determining physiologic response to various environmental noise sources.

Baker (1992) mentions that from various sensory organs, the ear developed in an evolutionary sense as an organ for perceiving and responding to danger. It is the auditory system that maintains arousal to the brain by the inner ear's direct pathway to the auditory cortex and indirect pathways to the reticular activating system and autonomic nervous system (Westman and Walters, 1981). Hearing is not voluntary and cannot be reduced when compared to vision, by simply closing one's eye (Baker 1992). Walters and Westman (1981) continue to say that noise can be harmful when it increases arousal and when there is an overload of information processing when it is unwanted.

Because of the numerous amounts of hospital equipment and abundance of patients and staff in a small and limited area, noise generated in the hospital unit is often high (Baker 1992). The average noise level in the intensive care unit was 72 db during the day, 65 db during the evenings, and 62 db at night with loud noises occurring every nine minutes (Bentley, 1977). Studies have associated high decibel levels with physiologic effects. The physiologic effects of noise are changes in heart rate, blood pressure, and respiratory rate all, of which were observed from normal subjects in a laboratory setting that had noise levels that were greater than 70 db (Falk, 1973).

Two separate studies conducted by Cartwright and Thompson (1975) and Andren and Hannson (1980) involved exposing young subjects to 85 to 95 db of industrial noise for a period of 20 to 60 minutes. They noticed that there was a cardiovascular response,

increased diastolic blood pressure, and various changes in heart rate. Baker (1992) implies that results from the above mentioned research indicated that there is a positive relationship between noise levels in a hospital and physiologic responses to patients.

### **2.3 Heart Response to Noise**

Several research studies were conducted to see how the heart responds to noise. Most of the studies conducted where in the critical care units because it is the location where most hospital monitors are used and where patients require significant amount of rest to recover. One study conducted by Marshall (1972) measured continuous sound levels in CCU patients rooms and categorized them as either human or nonhuman. Human would refer to any talking and nonhuman would refer to any hospital equipment. Marshall (1972) study involved sampling the heart rate every two minutes for every six hours, giving precise measures of the heart rate in association with corresponding noise sources. He found mean pulse rate increases in response to human sounds.

Another study conducted by Storlie (1976) measured heart rate change under low and high noise conditions in two CCU's. Storlie (1976) found that noise elicited heart rate change in 81% of subjects and of the patients with myocardial infarction, 94% had heart rate changes when exposed to noise. Furthermore, he performed a regression analysis, which indicated that the extent of heart rate change was positively correlated with history of heart disease (Storlie 1976). The third study conducted by Conn (1981) examined differences in heart rate, frequency of arrhythmias, as well as the anxiety state of 25 male patients in the CCU during quiet and noisy periods. Conn's (1981) study determined heart rate from a 1 minute ECG recording and noise levels recorded at one

minute intervals for five minutes between 3 and 4 p.m. and 7 and 8 p.m. He found a significant difference between anxiety state and the number of ventricular arrhythmias during noisy periods (Conn, 1981).

A final study conducted by Baker (1992) attempted to explore the correlation between source of noise, noise level, and its effect on heart response. The three research questions that need further examination (1) What are the noise levels in the ICU during evening hours (2) What is the change in heart rate of patients exposed to different noise levels in the ICU and (3) and what is the change in heart rate of patients in response to different noise sources in the ICU?

A total of 28 subjects took part in the experiment. The subjects had undergone abdominal, carotid endarterectomy, or peripheral vascular surgery and whose age ranged between 39 to 84 years (Baker, 1992). Patients who were excluded from the study included those that were not able to read or speak English and also those who were cognitively impaired. The study is initiated with a hearing test and was measured with a portable audiometer. Normal hearing was defined as a mean of less than 26 db from three decibel readings in the speech frequencies for the better ear and mild hearing loss was defined as a mean of 26 to 40 db (Goodman, 1965). Results from the testing have verified that 25% of the subjects had mild hearing loss but all were able to hear conversation at bedside (Baker, 1992).

Baker (1992) observed in the research study that the sound pressure level across the 6-hour observation time was 60.5 to 62.4 dBA. She also observed that the loudest hour (62.4 dBA) with the least change in noise level occurred between 3:00 and 4:00 p.m. (during shift change) and in between the hours of 4 and 6 p.m. where staff activity

consisted of performing assessments or procedures. Furthermore, the least amount of noise occurred between 7 and 8 p.m., times when nursing assessments were performed and completed and when visitors and physicians had already left. The noise types were categorized into four areas and included talking inside the room, talking outside the room, non-talking noise, and ambient noise. Noise periods during the period of observation were consistently above the 35 to 50 dBA recommended for rest and sleep (Walker, 1978).

A change in heart rate was observed along with an increase in sound pressure level. The heart rate of each patient was recognized when there was a noise episode of 3 to 6 dBA or greater. There were 23 episodes per patient throughout the 6-hour observation and of the 28 subjects, 86% had increases in heart rate more frequently than decreases and 46% had significantly more increases in heart rate (Baker, 1992). A heart rate change was also observed in response to different noise sources. Baker's study proved that the mean heart rate was highest for 16 subjects during talking inside the room, for 7 subjects during non-talking noise, and for 3 subjects during talking outside the room. The highest mean heart rate among all subjects was during talking inside the room (85 bpm); mean heart rate during non-talking noise was 83 bpm (Baker, 1992). Baker also observed that there was no difference in mean heart rate during talking outside the room and ambient noise.

## **2.4 Annoyance of Noise**

There are persistent physiological reactions to noise. Generally, it can cause sleep and performance decrements. Annoyance reactions to noise are often associated with reported interference of noise in everyday activities (Stansfeld, 1992). The interference then leads

to annoyance (Taylor 1984 and Hall 1985). Furthermore, Stansfeld (1992) suggests that noise is dependent on the context of which it is heard. Gunn (1987) further emphasizes that the meaning of a noise for any individual is important in determining whether that individual will be annoyed with it.

In most hospital studies, annoyance of noise was reported according to sources of noise, such as staff, other patients, equipment and background sounds and/or interference with activities (Baker, 1993). Approximately 30-70 percent of patients interviewed on open wards reported that they were frequently disturbed by conversation from visitors and staff, 40% of which the hospital noise involved staff talking, nurses talking and laughing outside of patients' rooms especially when they wanted to sleep at night (Baker, 1993). Personal variables may also be a contributing factor to noise annoyance since patients vary in age, gender, and medical condition.

Snook found that most patients annoyed by hospital noise were 40 to 59 year old men (Baker, 1993). People who are experiencing psychological distress or high levels of anxiety were also most likely to be affected by noise. If noise persisted, patients would then take action by complaining. Jonsson found that persons reporting the highest degree of annoyance had a greater proportion of physical symptoms associated with noise (e.g. headache, insomnia, and nervousness) (Baker, 1993). Jonsson also indicated that ones that were most likely to take action against noise are those from a higher socioeconomic status (Baker, 1993).

According to Baker, there are five important elements that define a patient's response to noise annoyance. (1) A known and recognizable physical sensory stimulus from persons or objects exists in the environment. (2) The stimulus is perceived by a

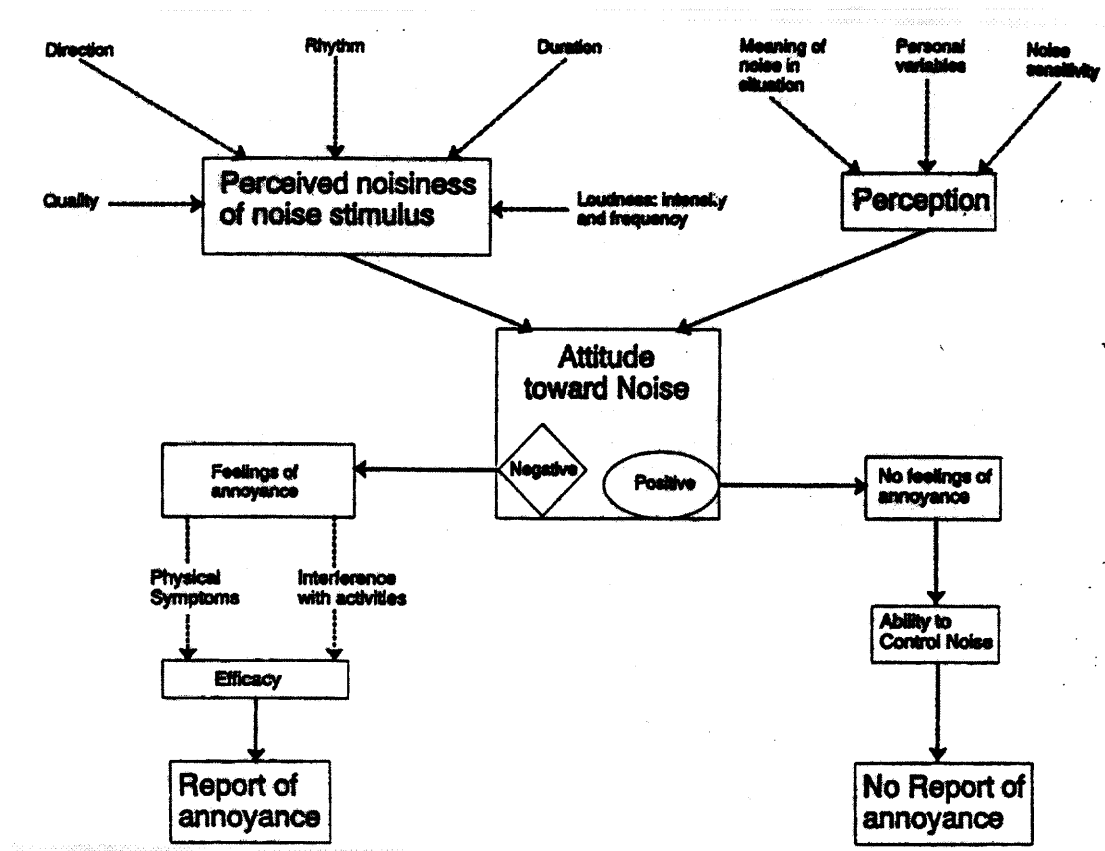
person through the sensory receptors. The person interprets the sound based on physical characteristics of the sound, context and source of the sound, noise sensitivity and other personal characteristics. (3) The degree of annoyance experienced by each person is dependent on attitude about noise, meaning of noise to the individual, activities that interfere with noise, and association of the stimulus with one or more source of annoyance. (5) The individual is able and decides to take action by making a complaint (Baker, 1993). Figure 1 illustrates a model of the physical characteristics of noise and how an individual perceives and response to noise.

## **2.5 Effects of Noise on Performance**

Although researchers have related negative findings to the effects of noise on performance, in some ways it provides evidence that noise has significant effects on performance and sleep (Loeb, 1986). The general themes of many complex noise influences on performance are that noise increases arousal and decreases attention through distraction (Broadbent, 1953), increased focusing or attention to irrelevant stimuli (Cohen and Spacapan, 1978) and latterly that noise alters choice of task strategy (Smith and Broadbent, 1981). Broadbent (1983) continues to say even relatively low levels of noise can have subtle ill effects on the state of a person.

Typically, multi-tasking conditions have caused decrements in work performance (Hockey, 1970). Noise may also affect social performance such as: (1) a stressor causing unwanted aversive changes in the current condition (2) masking speech and impairing communication and (3) distracting attention from relevant social cues (Jones, 1981). It may be that people whose performance strategies are already limited for other reasons

(e.g. anxiety) and who are faced with multiple tasks may be more vulnerable to the masking and distracting effects of noise (Stansfeld, 1992).



**Figure 2.1** The Model of Noise Annoyance illustrates the relationship between the physical characteristics of a noise stimulus, conditions affecting the individual's perception of noise, and the human response to annoyance.

## 2.6 Noise Regulation in Hospitals

Both the US Environmental Protection Agency (EPA) and International Noise Council have set standards that allow hospitals to control and maintain noise levels throughout the patients' hospital stay. The US Environmental Protection Agency recommends that hospital noise should be maintained at 40 to 45 dBA or lower to adequately prevent annoyance during the day, and recommend less than 35 dBA for sleep (Griffin, 1992).



The noise standard implemented by the International Noise Council for hospital acute care areas should not exceed on average, 45 dBA during the daytime, 40 dBA during the evening, and 35 dBA at night (Griffin, 1992).

Several research studies conducted show that noise levels in hospitals are generally above the recommended decibel levels. Sound level meters were used to obtain measurements in hospitals at various hours of the day. One study involved collecting data in various size intensive care units. According to the study, a 17 – bed recovery room averaged 57.2 dBA, a multibed room approximately 53 to 80 dBA, and the intensive care unit (ICU), an average of 58 to 72 dBA (Griffin, 1992). The studies further indicate that each area measured generated noise over 70 dBA and that it was high enough to interrupt patients' sleep or rest (Griffin, 1992). Another study conducted at an in patient naval medical center measured intermittent sounds. Areas included in the study were the intensive care unit, stairwell area, and nursing station located closest to patients' rooms.

The intensive care unit noise ranged between 50 to 80 dBA over a course of 24 hours, stairwell noise between 70 to 110 dBA, and nursing station between 60 to 70 dBA (Griffin, 1992). According to the research study conducted by Kam and Thompson, (1994) most hospitals have ambient noise levels of 50 to 70 dBA and averaging 65 dBA in the daytime and lowering to 45 dBA during nights. Their survey also indicated that the noisiest hours in the hospital occur in the late afternoon and early evening with the hospital staff members being the major contributor of noise during these times (Kam and Thompson, 1994).

## **2.7 Types of Noise**

Three classes of noise that can occur are intermittent, continuous, or impulse-type noise. Continuous noise is normally defined as a broadband noise of approximately constant level and spectrum to which a person is exposed for a period of 8-hours per day, 40-hours per week (Plog, Niland and Quinlan, 1996). Intermittent noise can be defined as exposure to a given broadband sound-pressure level several times during a normal working day (Plog, Niland and Quinlan, 1996). With steady noise, it is more efficient to record the *A* weighted sound level attained by the noise (Plog, Niland and Quinlan, 1996). The third type of noise is the impact type noise. It can be described as a sharp burst of sound that often produces peak levels of noise. Impulsive or impact type noise such as that made by a hammer blow or explosion is generally less than one-half second in duration and does not repeat more often than once per second (Plog, Niland and Quinlan, 1996).

## **2.8 Sleep Disturbance Due to Noise**

Many researchers have linked noise to sleep deprivation among patients in hospital settings. Several researchers attempted various experimental strategies in determining whether sleep deprivation can potentially slow patients' healing processes. A study conducted in Rhode Island Hospital's Respiratory Care Unit attempted to verify whether peak noise interferes with sleep. The study focused on hospital units with sound levels that were greater than or equal to 80 dBA and determined whether the peaks correlated with patients' sleep arousal. The study also involved monitoring patients' EEG levels in the intermediate respiratory care unit for an 8-hour period. Researchers hypothesized that

measured nocturnal environmental peak sounds of  $\geq 80$  dBA would be associated with EEG (electroencephalogram) arousals from polysomnographically recorded sleep in patients in the intensive respiratory care unit (Aaron and Carlisle, 1996).

Typically, noise level can be determined by using a sound level meter or by generating a questionnaire to subjectively rate and identify sounds that may be annoying to patients. In this study, both noise data and sleep data were collected from the intensive respiratory care unit (IRCU). Noise monitoring was conducted for 8 days in which repetitive sounds  $\geq 80$  decibels were observed. The sound levels were monitored in a location directly adjacent to the headboard of the selected patients (Aaron and Carlisle, 1996). Researchers decided to choose six patient volunteers who have adapted to the noise monitoring and have been stationed in their units for several days (Aaron and Carlisle, 1996). The 8-hour sleep observation was broken down into 30 - minute segments and any volunteer who experiences wake periods greater than ten minutes are dropped from the study (Aaron and Carlisle, 1996).

Table 1 refers to the sleep characteristics of the six patient volunteers. From the table, the sleeping stage data is expressed as a percentage of total study time (Aaron and Carlisle, 1996). The data indicates that the mean total sleep for the six patient volunteers reduced to  $325 \pm 33$  minutes (Aaron and Carlisle, 1996). In addition to the reduced amount of sleeping time, the mean sleep efficiency (total sleep/8-hour time period) was also low at  $68 \pm 7\%$  (Aaron and Carlisle, 1996). See Table 1.

A relationship between sound peak levels and sleep arousal was observed among the six patient volunteers. Researchers have concluded that volunteers experienced 612 arousals from sleep, with the value expressed as an arousal index (number of arousal

events /number of hours of total sleep time) of  $19 \pm 6$  (range 8-42) (Aaron and Carlisle, 1996). They also observed the number of sound peaks and a total of 585 peaks  $\geq 80$  dBA were recorded (Aaron and Carlisle, 1996). In Table 1, sound peak is expressed in sound peak index with a range of 3-34 events/hour of sleep and a group mean index of  $19 \pm 5$  (Aaron and Carlisle, 1996).

Figure 2 clearly shows the relationship of  $\geq 80$  dBA peaks versus the number of sleep arousals and indicates the very strong correlation for the 30-minute segment. Overall, the study proves that excessive noise is present in the intensive respiratory care unit and supports the theory of past investigations that noise is generally prevalent within the critical care units. In addition, elevated noise levels not only interfered with patients' sleep but also surpassed the EPA's recommended hospital noise levels.

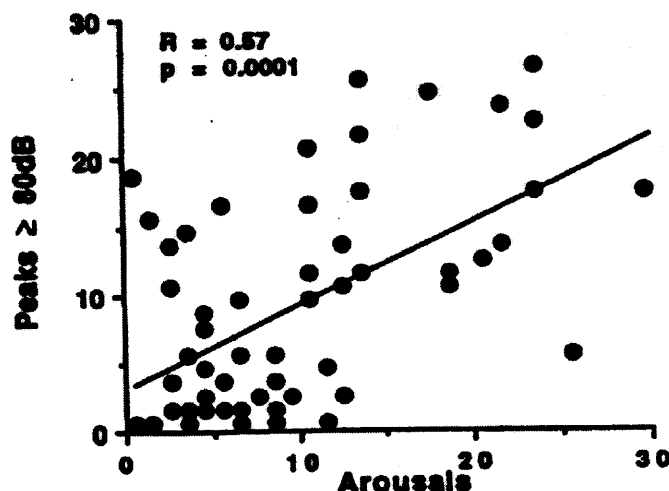
The effects of noise on sleep disturbance can either be subjective or objective (Ohrstrom, 1982; Ohrstrom *et al.* 1988). Researchers have investigated that there are repeated findings of individuals' differences in the susceptibility of sleep disturbance (Stansfeld, 1992). Sleep disturbance can include many noise sources. Rylander (1972) explains that excessive loud noise can lead to worse sleep quality, more awakenings, and even more morning tiredness. A study conducted by Aaron and Carlisle on sleep characteristics is illustrated below.

**Table 2.1** Illustrates data of sleep characteristics (from 8-hour sleep observation) of six patient volunteers. The data shows that the mean total sleep of the volunteers reduced to  $325 \pm 33$  minutes and that the mean sleep efficiency was also low at  $68 \pm 7$  (Aaron and Carlisle, 1996).

Patient	Awake %	Stage 1 %	Stage 2 %	Stage 3-4 %	REM %	Total sleep time (minutes)	Sleep efficiency %	Arousal index <sup>a</sup>	Peak sound index <sup>b</sup>
1	35	3	44	3	15	313	65	28	29.2
2	31	6	49	7	7	333	69	9.5	11.1
3	47	2	52	0	0	257	54	7.9	27.0
4	4	0.5	74	18	4	461	96	10	3.2
5	52	5	31	2	11	233	49	13.6	7.2
6	27	66	7	0	0	350	73	41.9	34.2
Mean $\pm$ SE	$33 \pm 7$	$14 \pm 11$	$43 \pm 9$	$5 \pm 3$	$6 \pm 3$	$325 \pm 33$	$68 \pm 7$	$19 \pm 6$	$19 \pm 5$

<sup>a</sup> Events per hour of sleep.

<sup>b</sup>  $\geq 80$  dBA per hour of sleep.



**Figure 2.2** Illustrates the relationship between the number of sound peaks of  $\geq 80$  dBA and the number of arousals from sleep for 30-minute segments recorded in six subjects between 2200 and 0600 hours. Thirty-minute segments were excluded from analysis if they included 10 or more minutes of wakefulness (Aaron and Carlisle, 1996).

## 2.9 Noise Comparison in Small and Large Area Hospitals

Noise studies were performed in two hospital settings to determine sound levels in acute patient care areas. The focus of the study involved 25 subjects from 4 intensive care units and 2 general care units. Researchers obtained continuous and intermittent sound

pressure level readings, they also conducted subjective interviews on how each patient perceived noise. This particular study defines noise at sound levels above those recommended for hospitals and relates the high level noise to what patients perceive as undesirable (Hilton, 1985). In reference to tolerating noise, an ill person would have a lower threshold when compared to a healthy individual. An ill person would also experience the noise as a stressor, which in turn could possibly impede healing (Hilton, 1985).

Basically, the aim of the study was to determine baseline information of sound generated in the patient care areas, with special emphasis on the sound source, sound level, and patient's experience on noise, and finally, method of intervention (Hilton, 1985). The equipment used to measure noise included a microphone, sound level meters, and two data recorders. The microphone was attached to a sound level meter; it was then connected to a data recorder that suspended on the headboard of each subject's bed.

Noise monitoring for each subject continued for a period of 24 hours. Upon completion of retrieving data, the sound level meter was connected to the data processor which, allowed data to be analyzed for selected time intervals (1 min., 15 min., 1 hour, and 24 hours) (Hilton, 1985). For every 24-hour period, the data retrieval unit averaged sound measurements for 1 minute, 15 minutes, 1 hour, and 24 hours. Subjective data was also collected from patients who were asked to reply verbally to short noise questionnaires. The patients were asked if noise levels in their area were acceptable and if in disagreement, what was annoying and how did it affect them (Hilton, 1985).

Results from the study concluded that smaller hospitals generated less noise when compared to larger hospitals (Hilton, 1985). Sound levels of smaller hospitals varied

from 32.5 – 57 dBA in the two intensive care units (ICU) and 34.25-62.5 dBA in the medical ward unit (Hilton, 1985). Researchers further observed that even though it was a small hospital, the noise level never fell below 36.5 dBA. In contrast to the small hospital setting, the large hospital noise levels consistently remained above 50 dBA and peaked to 68.5 dBA within a 24-hour period (Hilton, 1985). Nights were also found to be quieter in smaller hospitals and intermittent noise was also less than that compared to larger area hospitals. The noise source and decibel levels generated from the hospitals are further detailed in Table 2.

**Table 2.2** Illustrates the range of sound levels recorded in four ICUs and two general Medical / Surgical Units (Hilton, 1985).

Source	dB(A)	Source	dB(A)
Message tube	90–100	Cutlery/eating noises	53–72
Bedrails down/up	46–92	Plastic package opened	55–72
Things dropped/bumped	47–90	Cupboard doors opened/closed	40–70
Items set on shelves	48–88	Water running	44–70
Garbage cans moved on floor	48–83	Cotton curtains opened/closed	41–70
Doors opened/closed	50–80	Voiceover intercom	60–70
Refrigerator doors opened/closed	40–80	X-ray equipment moved	60–70
Things thrown into garbage can	67–80	General care of others	52–70
Automatic IV alarm (IVAC)	44–80	Beepers	40–69
Overhead IV pulled down	65–80	Ventilator buzzer	67–68
Cardiac monitor alarm	44–78	Radio	42–66
Computer printer	44–77	Patient weighted/scale moved	60–64
Toilet flushed	44–76	General movement noise	60–64
Ice machine	42–75	Call bell lights	48–63
Drawers opened/closed	40–75	Oxygen by mask	63
Carts	45–74	Elevator doors opened/closed	42–60
Trucks collecting garbage	54–74	Hopper flushed	44–60
Maintenance personnel	68–73	Videotape	38–56
Housekeeping personnel	45–73	Plane flying overhead	45–55
IV poles moved (wheels)	44–73	Oxygen by nasal prongs	49

## CHAPTER 3

### METHODS

#### 3.1 Equipment

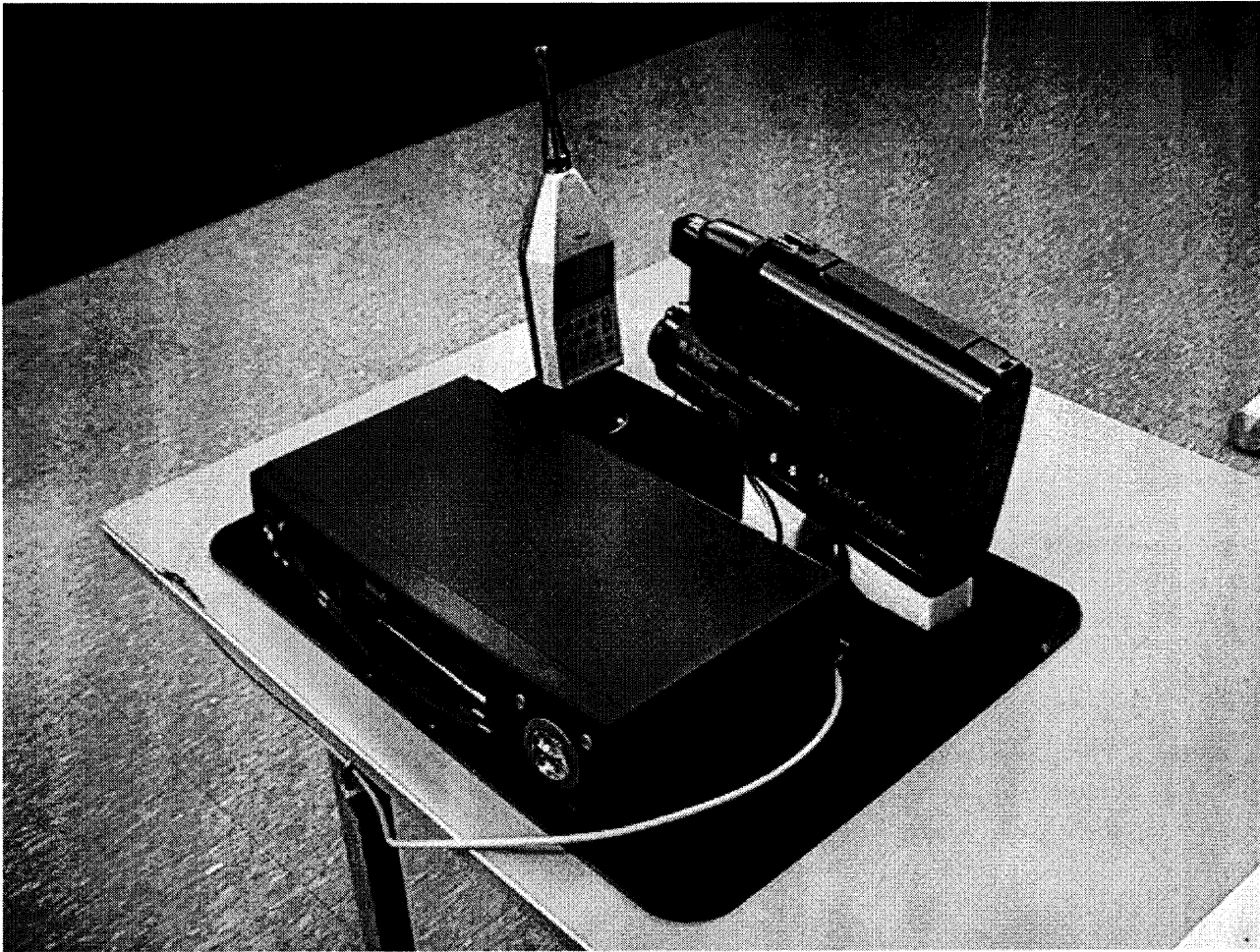
The equipment used for collecting noise data consisted of an NL-04 model RION integrating sound level meter, a VCR, camcorder, pocket sized television, and timer. All electrical cords were connected to one main power source before it was plugged to the timer. A specific start and end time was preset on the timer to preserve the life of the equipment and prevent it from malfunctioning while in continuous operation for 8 hours/day. The camcorder was angled and focused on the sound level meter to capture digital decibel levels and time. A VCR was essential to the study since the recording time of the camcorder alone would not be sufficient to capture eight hours of noise data.

The sound level meter displayed noise measurements by numerical and graphical results with the graph scale range preset to a range of 40 dBA to 90 dBA. Other preset functions of the sound level meter include a measurement time of *24 hours* with a mode of *Lp* in *A* frequency and *slow* response, which is suitable to check average levels of noise signals with little fluctuation. Noise usually measured in dBA scale, is a frequency-weighted scale that filters out frequencies below 1kHz (Kam and Thompson, 1994). Figure 3.1 displays an image of the equipment setup.

#### 3.2 Procedure

The setup location for the noise equipment was on the 10<sup>th</sup> floor of the hospital's Pulmonary Unit. It was situated on the countertop of a nursing substation where hospital staff would often gather. This particular substation was chosen because of its centered





**Figure 3.1** Equipment setup used for capturing noise. A tape is inserted in the VCR while the video camera records noise readings from the sound level meter.

location within the floor and its high level of work activity and interaction among staff. The substation also housed various medical supplies needed for patients. In addition, the station also held a computer workstation, small closet, and two telephones with paging options, sink, and towel dispenser. Adjacent to the nursing substation are the patients' rooms and directly across from it is a utility closet.

Due to the extensive size of the hospital's Pulmonary Department, only the nursing substation and adjacent areas were monitored for noise. Data points generated by

the sound level meter were recorded via VCR during Sunday through Friday between hours of 10:00 p.m. through 6:00 a.m. The decibel levels from the first five (5) seconds of every minute of each of the eight-hour tapes were recorded and a total of 2400 data points were collected from each of seven tapes. Due to discrepancy found in two videotapes, only five (5) were analyzed. The five tapes comprised of recorded hospital noise activity that occurred on Monday, Tuesday, Wednesday, Thursday, and Friday. Days of recording were random and did not necessarily follow consecutive days of the week.

The equipment setup was placed in the same area of the nursing substation during each day of the week and before initial setup, the hospital staff were made aware of what will be recorded and how the noise level meter functions. Subsequent to videotaping the noise collected from the sound level meter, a new videotape was re-inserted and ready to record for the next day. Collecting noise data spanned for a period of approximately four weeks. A few trials were conducted in the Pulmonary Unit to test the equipment prior to the actual data collection.

The noise data was collected by playing and pausing the videotape after recording the first five seconds of every minute on an Excel spreadsheet. This method of collection was completed for each of the five tapes and with further assistance from the hospital staff, it was possible to identify the high noise moments. In order to get a general idea of noise activity, a statistical mean, minimum and maximum value was generated for each day of the week (Monday, Tuesday, Wednesday, Thursday, and Friday). An analysis and interpretation of noise data is further detailed in Chapter 5.

## CHAPTER 4

### RESULTS

A nursing supervisor identified the Pulmonary Department as the largest and most chaotic among other units in the hospital (Personal Interview). Having been employed in the hospital for several years, she was most familiar with the common sounds and can identify them according to their source.

Aside from subjective data, part of the noise identification process involved isolating  $\geq 60$  dB peaks that occurred within each minute and identifying their source. Analyzing each of the videotapes revealed that most of the noise generated within the hospital unit is consistent and repetitious throughout the 8-hour work-shift. Decibel ranges varied greatly throughout each day. Data also suggests that peak noise is likely to occur at the start and end of the shift.

The 480 mean data points for each tape strongly suggests that peak noise occurs during the first two hours after shift change. Typically, part of the high activity is between the hours of 10 p.m. to 12 p.m. and then followed by quiet time between 1 a.m. to 4 a.m. Further observation of the data suggests that decibel levels are less likely to peak and are more constant (44.0 dBA - 51.0 dBA) between 1 a.m. to 4 a.m. It may be that between these hours there is less staff activity around the nursing substation. Beyond the hours of 4 a.m. activity begins to pick up again wherein the hospital staff tends to patients by changing their bed sheets and performing phlebotomy work until the early part of the morning. Table 4.1 illustrates the maximum and minimum noise levels generated in each workday.

**Table 4.1** The minimum and maximum noise level observed from each day of the week.

<b>Observed Days</b>	<b>Decibel Range / Workshift (dBA)</b>
Day 1	43.50 – 70.90
Day 2	44.20 - 84.70
Day 3	44.00 - 71.40
Day 4	44.10 - 67.20
Day 5	44.10 - 67.20

Several noise sources were identified in the study and from observing each of the tapes, noise generated in the evenings seemed to occur at similar hours of each work-shift. It was also observed that the majority of the noise generated in the evening was from the hospital staff performing their routine tasks. A few sources of noise ranged from equipment alarms, wrappings on hospital supplies, patients screaming and overall hospital staff performing their daily tasks. The following table was constructed to represent the prevalent sources of noise that was observed in each work-shift.

**Table 4.2** The most prevalent source of noise observed from each work-shift and the corresponding peak level of that noise.

<b>Source</b>	<b>Peak Decibel Level (dBA) Observed</b>
Nursing Kardex Chart	66.8
Medication Cart door slamming	74.6
Glucometer tray	65.4
Opening syringe wrapper	64.1
Graduate cylinder dropping	89.5
Medication cart drawer slamming	70.8
Bedside binders opening and closing	78.3
Utility closet closing	73.9
Conversation between 2-3 people	82.5
Cough	63.8
Group laughter	69.3
Hanging up telephone	67.3

Most of the noise generated each evening on the hospital floor includes manipulating the Kardex chart, slamming the doors and drawers of the medication cart, opening and closing binder rings, opening syringe wrappers and flipping off caps from vials, and the overall loudness of conversation.

Data collection also included, calculating a statistical mean, minimum, and maximum value that will obtain values for the distribution of average sound levels generated within each minute and also, the occurrence of decibel change that occurs within each minute. The difference between the maximum and minimum values as well as the changes that occur within each 5 seconds/minute is graphically interpreted over an 8-hour time period. The average decibel level per minute and peaks per minute that occur over an 8-hour time period are also graphically interpreted (See Appendix).

**Table 4.3** Distribution of (maximum-minimum) within each minute for 480 minutes

<b>Number of Occurrences per Day</b>					
<b>Mean dB Difference</b>	<b>Day 1</b>	<b>Day 2</b>	<b>Day 3</b>	<b>Day 4</b>	<b>Day 5</b>
0	0	0	0	0	0
0-2	157	234	234	166	226
2-4	138	113	113	111	120
4-6	79	54	54	92	58
6-8	46	34	34	54	31
8-10	24	18	18	23	17
10-12	15	14	14	15	15
12-14	11	5	5	9	5
14-16	3	5	5	3	4
16-18	3	2	2	3	1
18-20	3	1	1	3	1
>20	1	0	0	1	2
<b>TOTAL</b>	<b>480</b>	<b>480</b>	<b>480</b>	<b>480</b>	<b>480</b>

The compiled data from Table 4.3 categorizes the decibel ranges and distribution of noise level recorded during the five days. The number of occurrences is obtained from a difference in the minimum and maximum decibel value within the first five seconds of every minute. The number of occurrences can then be compared to the mean decibel difference to get an idea of how many times a certain decibel range is repeated within 480 minutes. A comparison within each of the five days shows that the highest number of decibel occurrence falls between the 0-2 decibel range. The number of occurrences between Day 1 to Day 5 ranged from 157 to 234 times per day. It was further observed that as the mean decibel difference increased the number of occurrences decreased. Only during Day 1, Day 4, and Day 5 did decibel levels in the unit peak to a mean decibel difference greater than 20.

Conversely, the distribution for the number of occurrences decreased as decibel levels approached the mean decibel difference of 12-14 through 18-20. These results are also an indication that peak noise levels, having a dB difference of 10 or greater occur about 5% of the time during an 8-hour work-shift. Noise peaks are often intermittent and sudden and can be identified by a sudden 10-decibel increase from the previous noise reading. From Table 4.3, it can be concluded that noise peaks do not occur often and are sporadically dispersed throughout the 8-hour work-shift whereas low dB noise appears to be more continuous and consistent throughout an entire shift.

The current mean minute average and previous mean minute average were subtracted to determine the mean increase/decrease decibel level between each minute. Table 4.4 below shows the distribution of the current average sound level that is higher than the previous average sound level. Results from the first row indicate that a change

in 0-2 dBA for each day of the week occurs more often in an 8-hour working period. The change in 0-2 decibel levels also occurs more often when compared to the rest of the mean dB differences.

**Table 4.4** Distribution of positive decibel change within each minute for 480 minutes

Note: Values were based on times when current minute sound level average is higher than the previous.

<b>Difference Between Current and Previous Minute Average</b>					
<b>Mean dB Difference</b>	<b>Day 1</b>	<b>Day 2</b>	<b>Day 3</b>	<b>Day 4</b>	<b>Day 5</b>
0-2	180	204	204	173	219
2-4	71	67	67	79	56
4-6	34	33	33	35	22
6-8	23	18	18	21	25
8-10	14	13	13	5	8
10-12	4	4	4	5	11
12-14	3	2	2	5	3
14-16	1	0	0	0	0
>16	1	2	2	3	3
<b>TOTAL</b>	<b>331</b>	<b>343</b>	<b>343</b>	<b>326</b>	<b>347</b>

It was observed that the greatest number of peaks (0-10 mean dB difference) occurred on Day 5 and that the highest mean decibel difference, greater than 16 dB, was present throughout each day of the week. The peak noise levels of greater than 16 decibels occurred at only 0.3% and are at the lowest frequency. Two statistical methods were used in determining if there are significant differences among the noise levels between the five days. The following section presents the detailed statistical analysis.

#### 4.1 Statistical Analysis

The analysis of variance (ANOVA) was applied to quantitatively analyze the data collected and to further examine the difference in values obtained from each of the tapes. It was chosen because it was the best method to use for comparing means of three or more samples. This method of analysis also aids in providing a comparison between the samples and determining whether significant noise level exists between each day. Daulton's Multiple Range Test was then applied to the noise data analyzed by ANOVA. The multiple range test involves sorting the means from highest to lowest and then testing it from highest to second lowest and so forth until all are tested against each other. The data and ANOVA table below summarizes the values obtained from the analysis. In addition, the method for collecting data was not in any particular order and began on a Tuesday and followed by Thursday, Friday, Wednesday, and Monday. Since the data collected represents noise within the five days, it does not indicate that each day of the week will have similar decibel levels therefore, Day 1, Day 2, Day 3, Day 4, and Day 5 will generally correspond to the weekday.

**Table 4.5** Data collected

<b>Treatment</b>	<b>Mean Total</b>	<b>Mean</b>	<b>Standard Deviation</b>
Day 1	22723.2	47.34	3.91
Day 2	23040.0	48.00	3.92
Day 3	23126.4	48.18	4.05
Day 4	23174.4	48.28	3.83
Day 5	22564.8	47.01	3.45
Total	114628.8		



**Table 4.6** Analysis of Variance

<b>Source of Variation</b>	<b><i>Df</i></b>	<b>Sum of Squares</b>	<b>Mean Square</b>	<b><i>f</i></b>
Treatments	4	596.77	149.19	10.13
Error	2395	35268.00	14.72	
Totals	2399	35864.78		

$$\alpha = .05$$

$$F_{.05, 4, 2395} \approx F_{.05, 4, \infty} = 2.37 \text{ (Critical value for F distribution)}$$

Results from this analysis indicate that there is a significant difference of noise level between the tapes. To determine which tapes are different in terms of their average noise levels, the multiple range test was applied. No significant difference was observed between the noise levels on Day 1 and Day 5. Similarly, no significant noise differences were observed between Day 2, Day 3, and Day 4. The noise difference between the Day 1/Day 5 group and Day 2/Day 3/Day 4 group was statistically significant.

#### Daulton's Multiple Range Test

$$S_{yi} = S_{qrt} (14.72568/480) = .17515$$

$$R_2 (2, \infty) = 2.77 (.17515) = .485$$

$$R_3 (3, \infty) = 2.92 (.17515) = .511$$

$$R_4 (4, \infty) = 3.02 (.17515) = .528$$

$$R_5 (5, \infty) = 3.09 (.17515) = .541$$

*Ranked the Means by lowest to highest*

$$\text{Day 5} = 47.01$$

$$\text{Day 1} = 47.34$$

$$\text{Day 2} = 48.00$$

$$\text{Day 3} = 48.18$$

$$\text{Day 4} = 48.28$$

*Compared the first highest to the second (and so on)*

$$\text{Day 4 vs 3} = 48.28 - 48.18 = 0.10$$

$$\text{Day 4 vs 2} = 48.28 - 48.00 = 0.28$$

$$\text{Day 4 vs 1} = 48.28 - 47.34 = 0.94$$

$$\text{Day 4 vs 5} = 48.28 - 47.01 = 1.27$$

$$\text{Day 3 vs 2} = 48.18 - 48.00 = 0.18$$

$$\text{Day 3 vs 1} = 48.18 - 47.34 = 0.84$$

$$\text{Day 3 vs 5} = 48.18 - 47.01 = 1.17$$

$$\text{Day 2 vs 1} = 48.00 - 47.34 = 0.66$$

$$\text{Day 2 vs 5} = 48.00 - 47.01 = 0.99$$

$$\text{Day 2 vs 5} = 47.34 - 47.01 = 0.33$$

### *Result*

Statically, there is no significant difference observed in noise level on Day 2, Day 3, and Day 4. No significant difference was also observed for Day 1 and Day 5.

## **4.2 Discussion**

Results obtained from the analysis clearly indicated that noise generated in the Pulmonary Department exceeds the recommended EPA hospital noise level. As mentioned earlier, hospital noise should be maintained between 40 to 45 dBA during the day and less than 35 dBA in the evening (Griffin 1992). Although the range of noise was relatively low between the hours of 1 a.m. to 4 a.m. and was between 44.0 dBA – 51.0 dBA, it surpassed the EPA recommended decibel level at night, which should be below 35 dBA. In addition to the high decibel levels, noise peaks of greater than 60 dBA were observed throughout the evening and night, periods when patients are sleeping.

Since the sound level meter was located in the nursing substation, a large amount of conversation among the hospital was observed in each of the tapes. Sounds ranged from gradual conversation to moments of intense laughter. Noise levels are not entirely from one source and are often combined with conversation. One example is the sound of

running water and 2-3 staff members talking and laughing, this produced a peak noise of 82.5 dBA.

Another high level source of noise was the medication cart. Throughout the observation period, the slamming of the drawers and doors of the cart seemed most prevalent. Depending on where the cart is located in reference to the nursing substation will determine how loud the noise is produced. Also, depending on where the carts are placed relative to patients' rooms will have an outcome of whether the noise is loud enough to disturb their sleep. For most of the observation periods, the sound produced by the medication cart alarm generated approximately 50 dBA but did not occur within a lengthy period of time. However, analysis of the five videotapes revealed that there was prevalent slamming of the cart doors, drawers, and opening of the syringe wrappers while providing medication to the patients.

In each of the five videotapes, high noise levels were observed from flipping the Kardex charts and opening and closing of binder rings. It was stated that certain binders remained at the patients' bedside and in some instances information contained inside the binders need to be replaced. Tape analysis clearly indicated that this task is commonly performed and is conducted during the evening hours and can generate a peak noise of 78.3 dBA.

#### **4.3 Recommendations**

Through a very brief interview with one of the nursing staff members, the Pulmonary Department is known to be the largest and most chaotic in comparison to other units in the hospital. With this concept in mind, it is expected that noise levels will increase during certain hours of the work-shift and especially when there is interaction among

staff and staff interaction between patients. In most cases, when a task is to be completed at a faster rate, higher noise levels are produced. The staff may have grown accustomed to their work environment and neglect to notice the importance of keeping hospital noise at low levels. Interventions within the department can aid the staff in becoming more aware of their work environment and how it ultimately plays an important role in patient recovery.

One intervention to reduce noise within the unit is to hold educational sessions. It is important to analyze and observe the unit activities in order to get an idea of what tasks may require improvement in terms of decreasing noise or perhaps what equipment utilized may need modification. Since the results of this study indicate that staff members handling equipment generate the majority of noise a general monthly or quarterly meeting can be scheduled to help them stay aware of noise issues in the unit. Scheduling a monthly meeting will also keep the staff abreast of current noise issues.

The staff may wish to consider distributing a survey to the patients. It can be distributed once or twice a year. Receiving patient feedback can be an opportunity for the staff to evaluate the different types of noise that patients find disturbing or disruptive. Information from a survey will also help the staff identify what the common noise sources are and where they originate.

Administrative controls may also be implemented and can include a common goal among the staff members reducing the overall unit noise levels. The staff can maintain a record keeping log of the major sources of noise and possible solutions or recommendations for keeping the noise level down. The log book could act as a foundation to the noise control program.

Another control measure for equipment noise reduction is to modify the specification of the equipment. The medication cart doors are constantly being opened and slammed shut thus producing startling and high levels of noise throughout the evenings. A modification to the cart could include placing an absorbent material between the door and the frame of the cart, which could reduce the loud impact when it is closed. However, certain equipment modifications may be difficult to make since the intended design may be compromised. Often it may be more feasible to replace the entire unit with a new one that considers noise level as a specification. Various medication carts are available for purchase and viewing on the internet. A few of the companies are Lionville Systems and Specialty Carts Inc. Lionville Systems carries medication carts of various models. Aside from standard specifications such as lightweight, security features, and wheels that easily roll, it stresses flexible design options. Having the option of personally designing the medication cart and tailoring it to the convenience of the staff and patients can help improve or lower noise generated from many of the currently used medication carts.

These recommendations were based on the re-occurring high noise levels observed in the unit. Particular attention should focus on the table of noise sources and the peak decibel levels they produce. No engineering controls are necessary but staff education, awareness, and equipment modification is recommended to lower the overall noise level in the Pulmonary Unit.

## **CHAPTER 5**

### **CONCLUSIONS**

From observing the data from the tape analysis, most of the noise generated in the Pulmonary Department is produced by the hospital staff. Previous research studies on noise have verified that conversation and interaction between the staff members contribute to an increase in noise level. An interview with one of the staff RNs revealed that a previous patient hospital survey was distributed in their department and results indicated that most patients were not bothered by hospital noise. Furthermore, she stated that patients prefer noise because it is an indication of activity and that there is someone out there.

Overall, this study verified that sound levels exceeded the EPA recommendation of 35 dBA for evenings. There was a great amount of talking and loud laughter observed in the nursing substation and in the surrounding areas. The nursing substation is a location of high activity and although it is located at the far end of the unit, it is still adjacent to patients' rooms, which makes them more susceptible to noise.

There were certain limitations encountered while collecting noise data from the nursing substation. One limitation is that the entire unit was aware of the study and can visibly see the sound level meter and camera. Seeing the camera and sound level meter may have affected the staff in behaving or performing their tasks routinely and as a result, certain sound levels or peak noise may not have been captured. Also, the staff was well aware of the microphone attached to the sound level meter. Analyzing the tapes revealed that certain staff members would test the sound levels of their voice by speaking directly to the microphone while others would feign a cough or produce irritating sounds.

One videotape recording captured a reflection off of the sound level meter showing a hand reaching behind the equipment and dropping an object. This activity indicates that the equipment location may have been an obstruction for the nurses and staff. The sound level meter and camera would have captured a wider range of sounds around the substation if the staff did not visibly notice the equipment.

Another limitation encountered in the study is that only one section of the Pulmonary Department was surveyed for noise. Since the unit is structured in a shape of a “U” and only one set of equipment was available, capturing noise was restricted to one area. Different noise sources and perhaps more activity may have been present on the other side of the Pulmonary Unit. The data obtained for this research is only a partial representative of noise created in the entire unit. Some of the noise observed on the videotapes was generated based on various concurrent activities and not independent noise sources.

The sound level meter was located on the edge of a table in the nursing substation. The amplifier and microphone connected to the meter was directly below another part of the table’s writing surface. It is difficult to pinpoint and determine the distance of the noise sources and how far the source is relative to the patients’ rooms. Directly opposite the substation is a patient’s room and therefore, noise peaks generated by the staff or equipment can clearly be a disturbance to the patients.

Although there were several limitations encountered during the study, there are several solutions to help in obtaining better equipment setup when analyzing and collecting noise data. A future noise study should include noise data from the entire unit because it will be a true representative of all the activities. Since there were discrepancies

observed on two of the research tapes, only the noise data from Monday through Friday were collected. Noise activities during the weekend could be different from the weekdays and could provide a true comparison of the staff's noise activity in a whole week.

Also, more observation time needs to be spent on the unit being monitored. It would be helpful in future studies to generate a questionnaire that can be distributed to the patients. Little to hardly any subjective feedback was obtained from the patients. It is important to gather a perspective on what they think about hospital noise and noise within their unit. Although the previously discussed literature review on noise annoyance verifies that it does affect patients' rest, it would also be beneficial to a study to ask what types of noise do they find bothersome and if possible, relate the noise to the work activity.

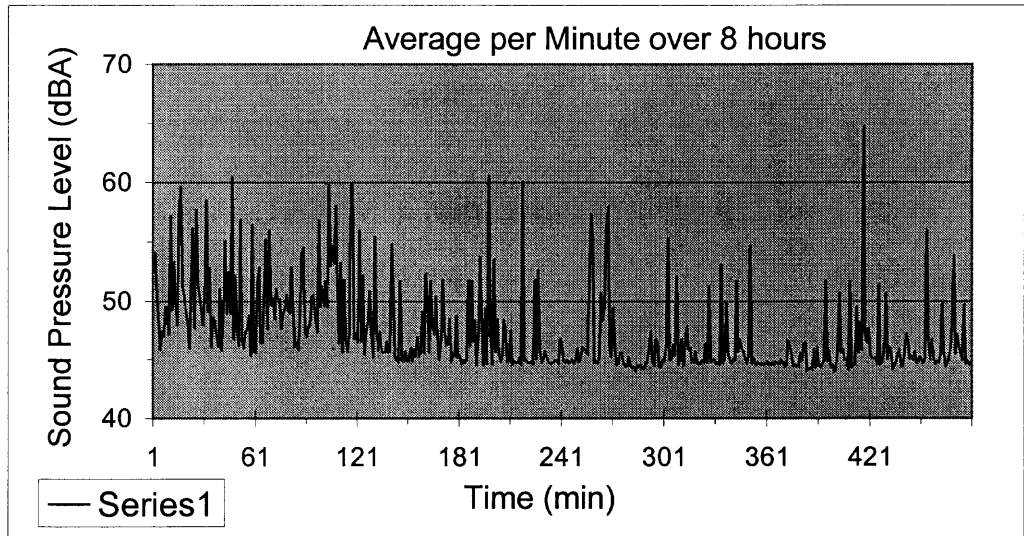
The equipment used for recording noise data was ingenious and sufficient for this study. However, there should be attempts to help facilitate the method of noise collection. Since future studies will most likely rely on obtaining more noise data, perhaps using a more sophisticated electronic equipment will be helpful. One option that should be made available is to include a connection between a laptop and sound level meter. The laptop in turn, should have a computer software program installed to make downloading noise data from the sound level meter to the computer easier. This concept will reduce the amount of human error and will be an effective, reliable, and accurate way to collect noise data points and eliminate the many hours spent in playing/pausing each of the 8-hour tapes.



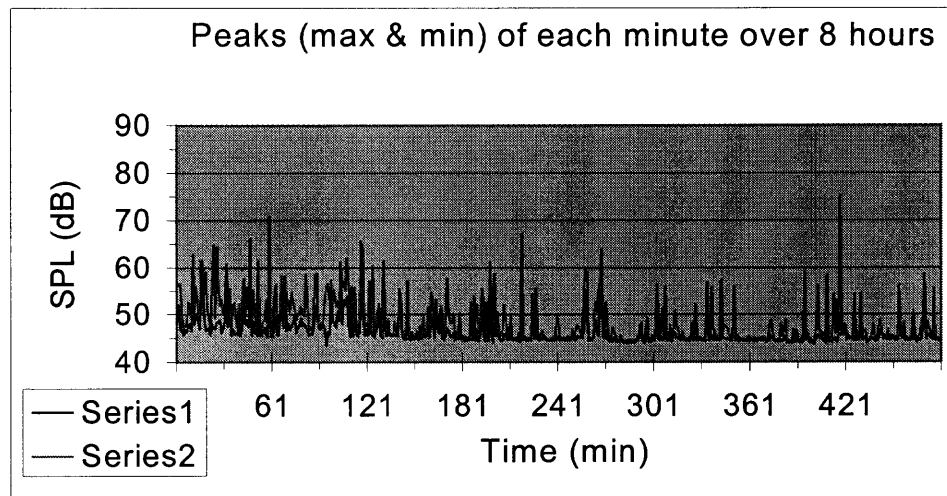
## APPENDIX

### Graphical Representation of Noise Peaks Per Minute over 8 Hours

#### Day 1

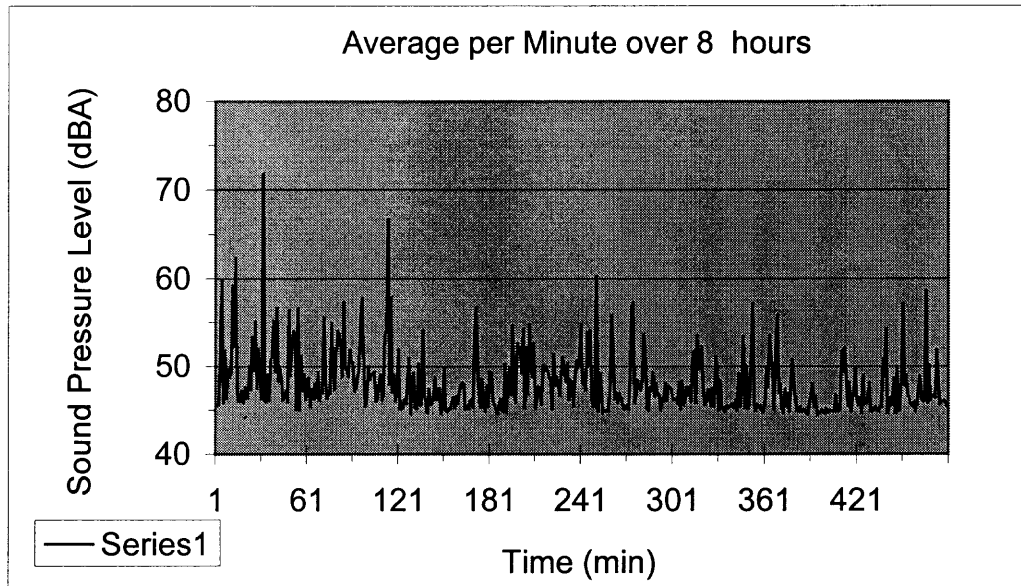


**Figure 1** The graphical representation of the mean decibel level of every minute over an 8-hour work-shift. Three peaks above 60 dBA were observed during this evening.

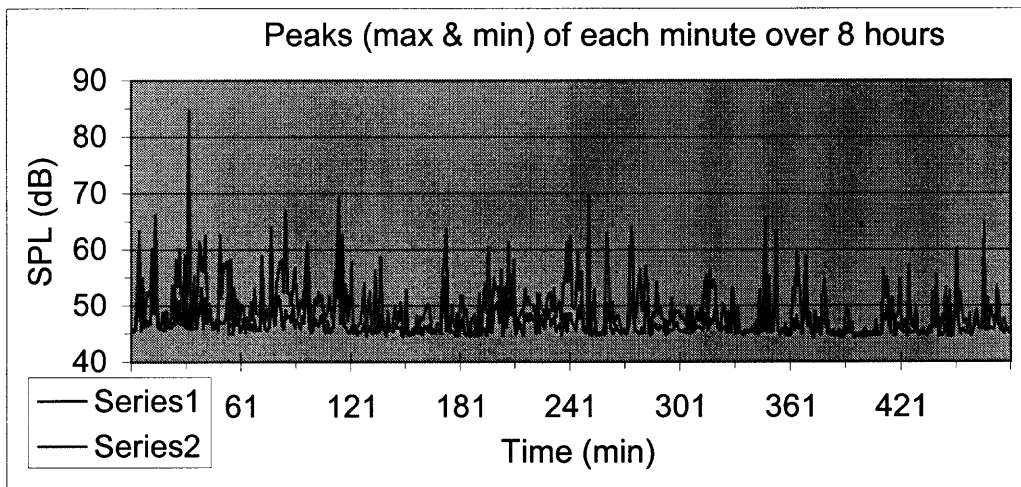


**Figure 2** Maximum and minimum peaks observed for every minute over an 8-hour work-shift. Series 1 signifies the minimum dBA level and Series 2 signifies the maximum. The maximum was 75.20 dBA and the minimum was 44.00 dBA

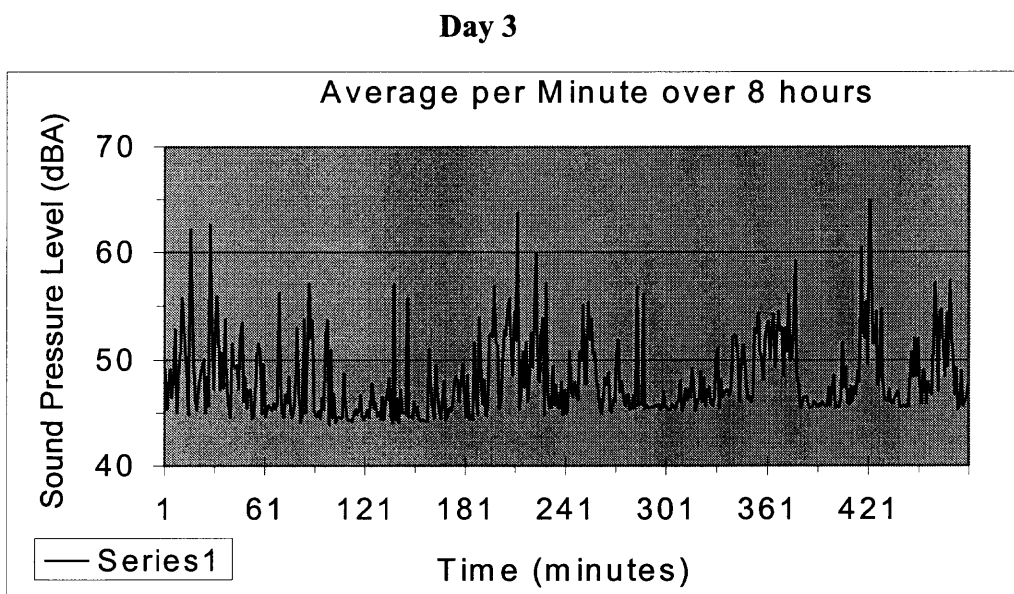
### Day 2



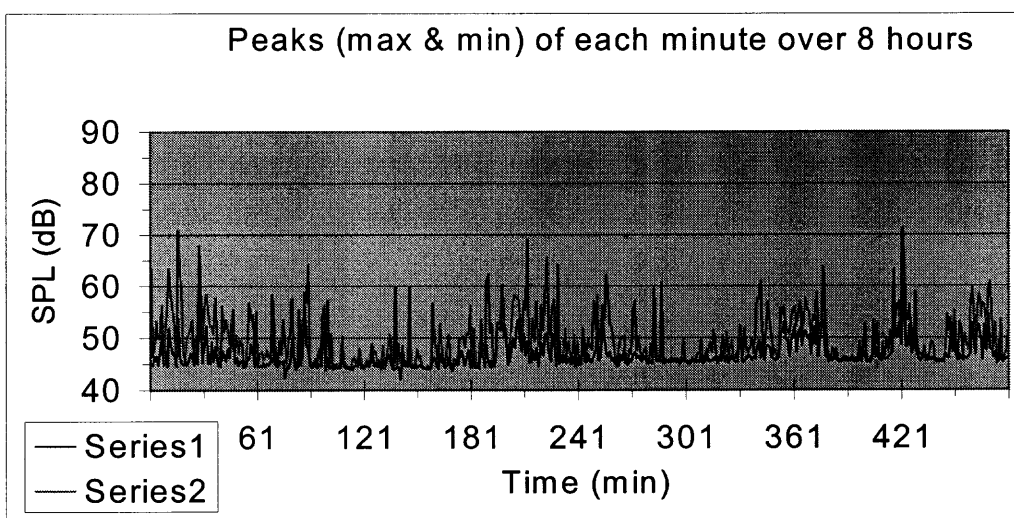
**Figure 3** The graphical representation of the mean decibel level of every minute over an 8-hour work-shift. Four peaks above 60 dBA were observed during this evening.



**Figure 4** Maximum and minimum peaks observed for every minute over an 8-hour work-shift. Series 1 signifies the minimum dBA level and Series 2 signifies the maximum. The maximum was 84.70 dBA and the minimum was 44.20 dBA.

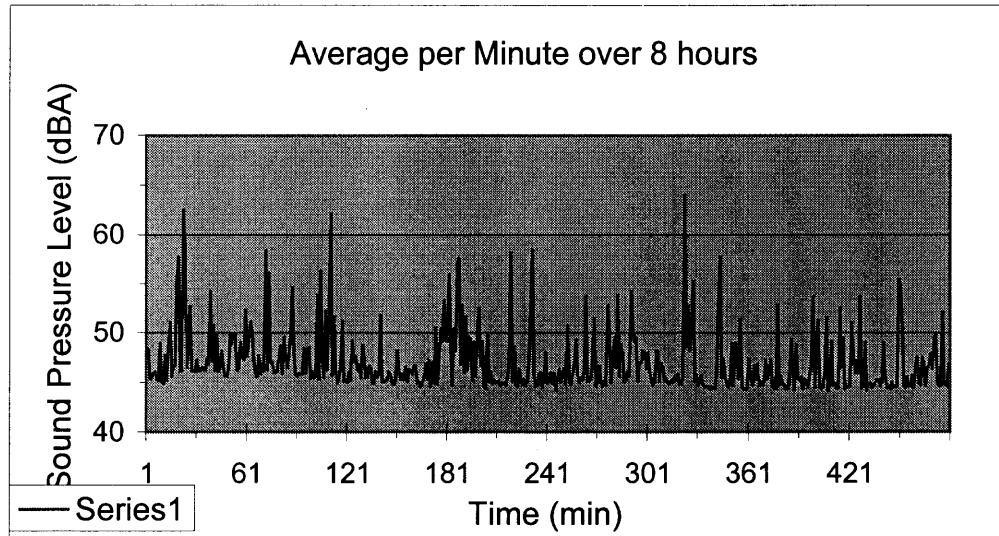


**Figure 5** The graphical representation of the mean decibel level of every minute over an 8-hour work-shift. Five peaks above 60 dBA were observed during this evening.

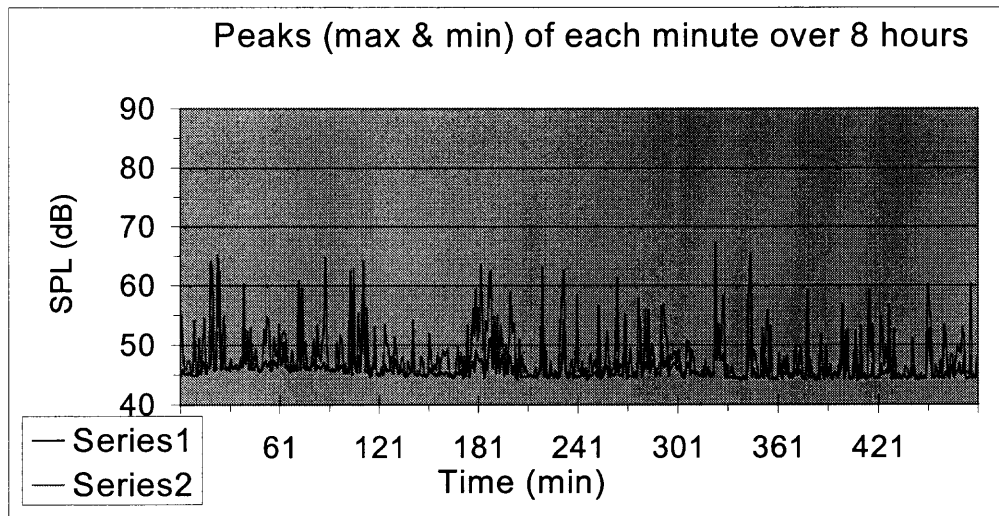


**Figure 6** Maximum and minimum peaks observed for every minute over an 8-hour work-shift. Series 1 signifies the minimum dBA level and Series 2 signifies the maximum. The maximum was 71.40 dBA and the minimum was 42.00 dBA.

### Day 4

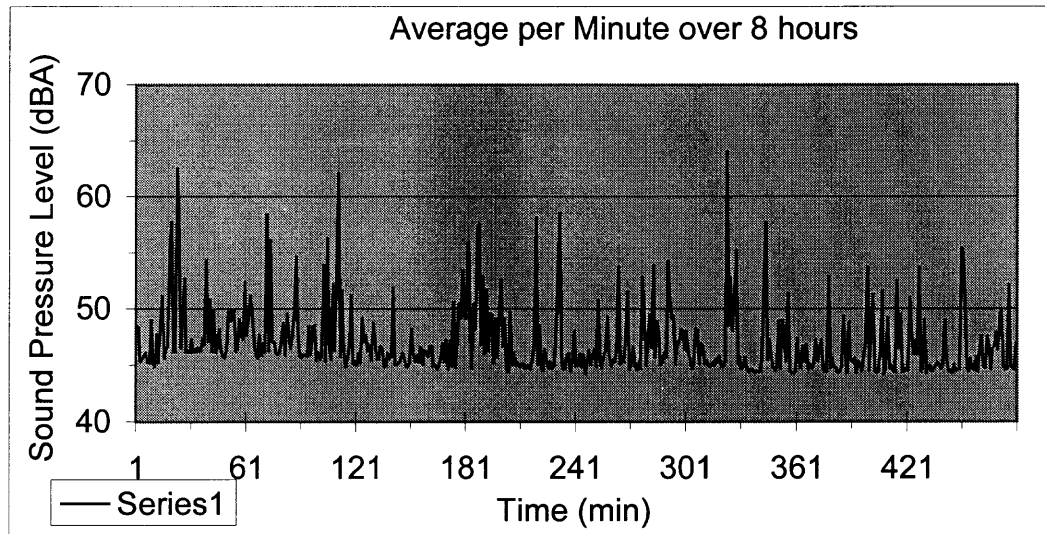


**Figure 7** The graphical representation of the mean decibel level of every minute over an 8-hour work-shift. Three peaks above 60 dBA were observed during this evening.

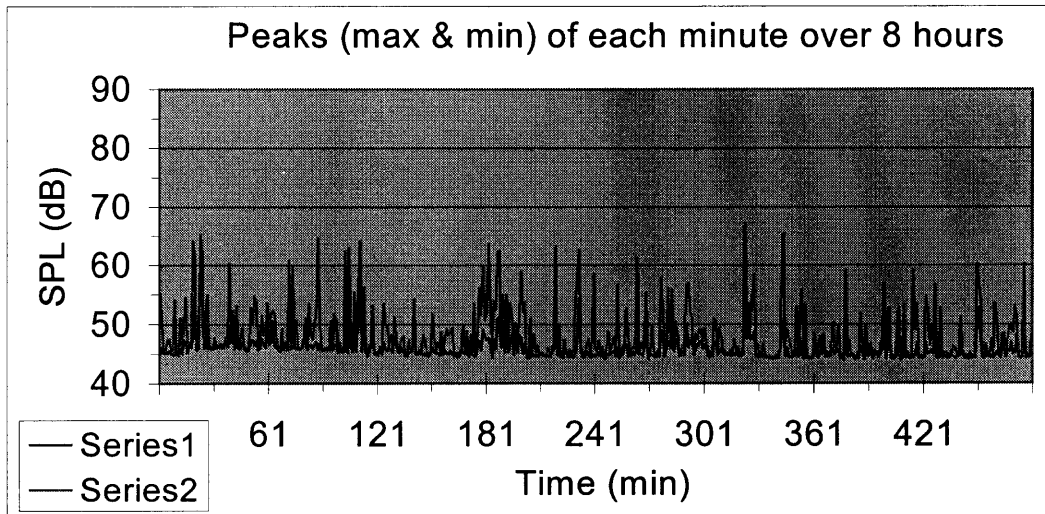


**Figure 8** Maximum and minimum peaks observed for every minute over an 8-hour work-shift. Series 1 signifies the minimum dBA level and Series 2 signifies the maximum. The maximum was 67.20 dBA and the minimum was 44.00 dBA.

## Day 5



**Figure 9** The graphical representation of the mean decibel level of every minute over an 8-hour work-shift. Three peaks above 60 dBA were observed during this evening.



**Figure 10** Maximum and minimum peaks observed for every minute over an 8-hour work-shift. Series 1 signifies the minimum dBA level and Series 2 signifies the maximum. The maximum was 67.20 dBA and the minimum was 44.00 dBA.

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