An Analytical Study Investigating Noise Levels in Neonatal Intensive Care Units within the Public Sector in the eThekwini District

By

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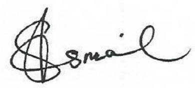
Declaration

I, the undersigned hereby declare that the work contained in this dissertation is my original work, except where references had been required in the text, were cited accordingly. This dissertation has not been submitted for the degree of Master of Audiology in the University of KwaZulu-Natal, Westville campus and has not been submitted before for any degree or examination at this or any other university.

Signature:  **Date:** 11 December 2018

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whose voice, I hope will be heard through this study.

Abstract

Noise is a well-documented environmental stressor in the NICU and has emerged as a public health problem. The aim of this study was to investigate noise levels and identify contributing factors to the high noise levels, in NICUs within the public sector in the eThekwini District. The study used an analytical observational research design and a purposive sampling method. Noise measurements were conducted in four hospitals with the sound level meter (CEL 450 C) placed in the centre of each NICU for 48 hours on two consecutive days of the week (Sunday and Monday). A sample of sources of noise and their frequency of occurrence were identified through direct observation in the morning, as well as a frequency analysis using one-third octave bands were conducted. Mean LAeqs were above 45dBA in all hospitals and a marginal difference between LAeqs during the morning, afternoon and night was seen in hospital D (p=0,046). A significant difference between LAeqs on Sunday and Monday was found in hospital C (p=0,028). The majority of the sources of noise were from alarms of devices and human-related noise, with the most frequently occurring sources of noise being staff conversations (30.9%), alarms (21,0%) and closing of metal pedal bins (20,0%). Multiple high frequency alarms increased the LAeq to 74,6dBA and dropping a metal object increased the LZpeak to 116,0dBA. LAeqs higher than 45dBA were seen in the mid and high frequencies (250Hz-6300Hz) specifically during the afternoon in all hospitals. The findings have implications for education and training, as well as for the development of practice and policy guidelines in NICUs.

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List of abbreviations

AAP – American Academy of Paediatrics

dBA – Decibel A-weighted

dB – Decibel

DoH – Department of Health

HPCSA – Health Professional Council of South Africa

HSSREC – Humanities and Social Sciences Research Ethics Committee

Hz – Hertz

LAeq – Equivalent A-weighted sound level

LAmin – Minimum A-weighted sound level

LAmax – Maximum A-weighted sound level

LZpeak – Peak Z-weighted sound level

NICU – Neonatal Intensive Care Unit

OSHA – Occupational Safety and Health Administration

PHREC – Provincial Health Research and Ethics Committee

SANS – South African National Standards

SLM – Sound Level Meter

US EPA – United States Environmental Protection Agency

WHO – World Health Organization

Definition of terms

A filter / A-frequency weighting filter – The A-frequency weighting is an electronic filter found in sound level meters (SLMs) (Behar, Chasin & Cheesman, 2000). Whenever sound is measured with this filter, results are expressed in the dB (A) (Behar et al., 2000). The A-weighted filter is scaled to the human ear to roughly capture the frequency response function of hearing (Gelfand, 2009). This frequency weighting network reduces the influence of frequencies below approximately 500Hertz (Hz) (Berger, Royster & Driscoll, 2003).

C-frequency weighting filter – The C-frequency weighting filter uses another frequency weighting network in the SLM. It does not have as substantial a low-frequency roll-off as the A-weighting network (Berger et al., 2003).

Central site procedure – The central site procedure involves positioning the SLM in the centre of each NICU. In an open nursery with excessive noise levels, central site measurements over a relatively short time most accurately reflect the noise exposure in the area (Nathan, Tuomi & Müller, 2008).

Decibel (dB) – The decibel (dB) is a logarithmic unit of measurement used to express the magnitude of a sound relative to some reference level (0 dB) (Behar et al., 2000).

Decibel A-weighted (dBA) – Noise is usually measured as A-weighted sound, which approximates human hearing and deemphasizes lower frequencies (Stafford, Haverland & Bridges, 2014).

Frequency – Frequency is defined as the number of times per second that a particle reaches the same position going in the same direction and is measured in Hertz (Hz) (Behar et al., 2000).

Gestational age – The gestational age of the neonate is calculated in weeks from the first day of the mothers last menstrual period, which should be approximately 40 completed weeks in human pregnancy (Jordan, Farley & Grace, 2018).

Hawthorne effect of attention bias – The Hawthorn effect of attention bias is when the study participant alters their behaviour when they are aware of being observed and avoids interferences that can cause another unexpected variable to influence the study (Fortes-Garrido, Velez-Pereira, Gázquez, Hidalgo-Hidalgo & Bolivar, 2014).

LAeq – The LAeq is an equivalent continuous A-weighted sound pressure level (Behar et al., 2000).

Lmax – The Lmax is defined as the highest decibel level measured for at least $1/20^{th}$ of a second during the hour (DeArmond, Yello, Bushait & Krueger, 2016).

LAmax – The LAmax is the maximum A-weighted sound pressure level over a period (DeArmond et al., 2016).

LAmin – The LAmin is the minimum A-weighted sound pressure level over a period (DeArmond et al., 2016).

Lpeak – The Lpeak is described as the highest sound pressure level reached at an instantaneous time during the measurement period (Stafford et al., 2014).

LZpeak – The LZpeak is the peak value of an instantaneous sound pressure level using a flat or zero frequency weighting network (Narang & Bell, 2008).

L10 – The L10 is the level of sound exceeding 10% of the time during the specific time interval of measurement (DeArmond et al., 2016).

Neonatal Intensive Care Unit (NICU) – The NICU is described as a unit at a hospital that must be separate from the new-born nursery providing intensive care to all sick neonates including those with the very lowest birthweights (<1500g) (Howell, Richardson, Ginsburg, & Foot, 2002).

Noise – Noise is a harmful or disturbing sound - harmfulness is the more objective of the two, whereas disturbance or annoyance caused by noise are more subjective concepts (Pulkki & Karjalainen, 2015).

Octave band analysis – Octave band analysis is when a broad frequency range is separated in to smaller units for analysis with the use of a bandwidth. The most common bandwidth or range of frequencies used for noise measurements is the octave band (Berger et al., 2003).

One-third octave band analysis – One-third octave band analysis is when more detailed characteristics of noise are required, such as to determine a noise source in the background of other sources, then it is necessary to use frequency bands narrower than octave bands, such as one-third octave bands (Berger et al., 2003).

Premature or Preterm – Prematurity is defined as neonates born alive before 37 weeks of gestational age (World Health Organization [WHO], 2015).

Slow response – SLMs have 'slow' and 'fast' response speeds, although the Occupational Safety and Health Administration (OSHA) requires most noise assessments to be made at the slow speed (Gelfand, 2009). The slow speed has a time constant of one second, which allows the averaging out of sound level fluctuations, making the meter easier to read (Gelfand, 2009).

Sound – Sound is formally defined as the fluctuations in pressure above and below the ambient pressure of a medium that has elasticity and viscosity (Berger et al., 2003).

Sound level meter (SLM) – A SLM is an electronic device that measures sound pressure levels and is equipped with various functions to determine the nature of the sound in the environment (Berger et al., 2003).

Sound Pressure Level (SPL) – Decibels in sound pressure level, or dB SPL, refers to the magnitude of the displacement of molecules in the air (Gelfand, 2009).

Chapter 1. Introduction

1.1 Introduction

This chapter provides an overview of the study, the nature and extent of the research problem, the rationale for the study, as well as recommended standards for noise in hospitals. It also provides the research question and includes an outline of chapters to follow.

1.2 Study Background

A Neonatal Intensive Care Unit (NICU) is defined as a place of care for medically unstable or critically ill neonates requiring continuous nursing, respiratory support and other intensive interventions (White, Smith & Shepley, 2013). A premature or preterm neonate is described as a neonate born before 37 weeks of gestation (Manske, 2017). Preterm and severely ill neonates depend on the NICU for continued support and normal development. Therefore, it is essential that they encounter a tranquil and intra-uterine experience to replace the time they lack in the womb (D'Souza et al., 2015; Carvalhais, Silva, Xavier, & Santos, 2016). In combination with a multidisciplinary team and a variety of operating equipment, the NICU can be a noisy and bright place where many stressors are common (Lejeune et al., 2016).

Noise is one of the well-documented environmental stressors in the NICU and has emerged as a public health problem (Thakur, Batra & Gupta, 2016; Gallo & Olivera., 2016; DeArmond, Yello, Bubshait & Krueger, 2016; Lejeune et al., 2016). Noise had been identified as a health risk in hospitals over 150 years ago by public health pioneer Florence Nightingale (Mazer, 2009). The hospital setting in the mid-19th century may not compare with the present auditory environment that consist of technology driven services, highly advanced institutional care and increasing patient populations, although the effect of noise on patients has not, and may be unlikely to change (Mazer, 2009). Research has given special attention to the adverse effects of noise on preterm neonates, due to their unique vulnerability and the physiological immaturity of their central nervous system (CNS) (Zimmerman & Lahav, 2013; Smith, Ortmann & Clark, 2018).

Despite the decline in mortality rate of preterm neonates over the years, the likelihood of CNS disturbances has increased, which may be due to overstimulation during time spent in the NICU (Matook, Salibury, Lester, Sullivan & Miller, 2010; McMahon, Wintermark & Lahav, 2012; Valizadeh, Hosseini, Alavi, Asadollahi & Kashefimehr, 2013; Neille, George & Khoza-Shangase, 2014; Manske, 2017). Preterm neonates are at a critical period for auditory development making it essential that that they are provided with appropriate auditory input and careful protection against overstimulation during their prolonged stay in the NICU (McMahon et al., 2012; Lahav & Skoe, 2014; Venkataraman, Kamaluddeen, Amin & Lodha, 2018; Cohn, 2018).

Stimulation of the auditory system can begin as early as 20 to 25 weeks of gestational age because all the major structures of the inner ear are already developed and functional (Cohn, 2018, Thakur et al., 2016). Therefore, intense sounds presented to the neonate, can result in adverse physiological effects, such as increased blood pressure, heart rate, respiratory rate and decreased oxygen saturation (McMahon et al., 2012; Thakur et al., 2016; DeArmond et al., 2016; Joshi & Tada, 2016; Cohn, 2018, Venkataraman et al., 2018), as well as sleep disorders (McMahon et al., 2012; Thakur et al., 2016; Cohn, 2018; Venkataraman et al., 2018).

The adverse physiological effects are likely to be intensified as the neonate is unfamiliar to the acoustic environment of the NICU, because it is quite different from that of the womb (McMahon et al., 2012; Lahav & Skoe, 2014). In the womb the foetus is exposed to a precise mixture of low frequency sound, such as the mother's heartbeat and voice with background noise from the mother's internal organs, which are transmitted through the amniotic fluid and the bones of the foetus's skull (Lahav & Skoe, 2014; Picciolini et al., 2014; Smith et al., 2018, Venkataraman et al., 2018).

The optimal environment present in the womb is abruptly terminated when the preterm neonate enters the suboptimal environment of the NICU, which is known as the acoustic gap between the womb and the NICU environment (Lahav & Skoe, 2014; Cohn, 2018). The untimely exit from the womb to the NICU, exposes preterm neonates to the direct exposure of airborne sounds across the entire frequency range when their auditory system is likely to still be accustomed to listening to low frequency sounds through the bone (Lahav & Skoe, 2014).

Hence, overexposure to constant noise, specifically at high frequencies while the auditory system is still developing can alter the natural development of the auditory pathways and disrupt the appropriate fine tuning of hairs cell in the cochlea (McMahon et al., 2012; Lahav & Skoe, 2014; Cohn, 2018). The preterm neonate who is exposed to constant high noise levels in the NICU, may also lack exposure to more natural sounds such as speech sounds, especially from the maternal voice, which has shown to facilitate growth and recovery as well language development (Ramm, Mannix, Parry & Gaffney 2017; Filippa et al., 2017; Sinha & Kumar, 2018). Therefore, there is reason to suggest that the acoustic gap can adversely affect auditory development, and result in delayed speech and language acquisition, which is often seen in the preterm population (McMahon et al., 2012; Lahav & Skoe, 2014).

Considering the effects of noise, many studies have focused on creating the ideal acoustic environment for the vulnerable neonate, however the current noise recommendations for hospitals were established decades ago and may not be suitable for the NICU (Smith et al., 2018). In 1974, the United States Environmental Protection Agency (US EPA) recommended that indoor hospital areas maintain an average sound level of less than or equal to 45 decibels, A-weighted (dBA) during the day and 35dBA during the night (Committee on Environmental Health, 1997). In 1997, the American Academy of Paediatrics (AAP) recommended that noise in the NICU should not exceed 45dBA, however the recommendation was applied from the US EPA, that referred to indoor hospital's areas and not specifically NICUs (Committee on Environmental Health, 1997; Knutson, 2012; Smith et al., 2018). Similarly, the World Health Organisation (WHO) and the South African National Standards (SANS) developed guidelines for noise levels in hospitals but it refers to noise in normal ward rooms and not specifically the NICU (Berglund, Lindvall & Schwela, 1999; SANS, 2008).

Research groups have re-evaluated the AAP recommendation and provided additional recommendations, which consider the presence of transient sounds in the environment that should not exceed a maximum level of 65dBA for maximum speech intelligibility, uninterrupted sleep and freedom from acoustic distraction (Graven, 2000; White et al., 2013). However, researchers argue that the recommendations may not be justified, and the goal should be to create a standard that promotes auditory development, while still maintaining a level of speech intelligibility in the NICU (Knutson, 2012). The present study used the AAP recommended standard for noise levels, as it refers to the NICU and is commonly used in other studies measuring noise in this setting. Table 1.1 outlines the recommended standards and guidelines for noise in hospitals specified by various organisations.

Table 1.1

Recommended Noise Levels for Hospitals

Organization	**Recommended values**
Committee on Environmental Health-American Academy of Paediatrics (AAP)	LAeq of 45dBA, Hourly L10 of 50dBA, LAmax of 65dBA in the NICU, A-weighted, Slow response (Graven, 2000; White et al., 2013)
United States Environmental Protection Agency (EPA)	45dBA (day time), 35dBA (night time) (Committee on Environmental Health, 1997)
World Health Organization (WHO)	For areas where patients are treated or observed-LAeq (35dBA), for wardrooms in hospitals-LAeq (30dBA) with an LAmax of 40dBA (Berglund et al, 1999)
SANS 10103:2008: The measurement and rating of environmental noise with respect to annoyance and to speech communication	LAeq (35dBA) in general wards (Van Reenen, 2016)

Note. LAeq: Sound levels equivalent to the total sound energy occurring over a selected period using A weighting; LAmax: Maximum sound levels recorded over a specific time interval using A weighting; L10: The level of sound exceeding 10% of the time during the specific time interval of measurement.

Despite the existence of recommendations, various studies analysing noise in the NICU have indicated that noise levels well exceed the 45dBA recommendation (Konkani & Oakley, 2012; Neille et al., 2014; Joshi & Tada, 2016; Connor & Ortiz., 2016; DeArmond et al., 2016; Romeu, Cotrina, Perapoch & Linés, 2016; Thakur et al., 2016, Carvalhais et al., 2016). Moreover, research indicate that the high noise levels may be closely related to the time of day, although discrepancies exist between which time of the day may be the loudest, but the majority of studies indicate that noise levels are higher during the morning (Matook et al., 2010; Valizadeh et al., 2013; Fortes-Garrido, Velez-Pereira, Gázquez, Hidalgo-Hidalgo & Bolivar, 2014; Joshi & Tada, 2016; Carvalhais et al., 2016; Cohn, 2018). Previous research has also found that specific days of the week have higher noise levels, especially on weekdays than weekends

(Matook et al., 2010; Carvalhias et al., 2016; Cohn, 2018). Therefore, measuring the noise levels during different times of the day and different days of the week can provide important information on understanding how the activities found on these days may contribute to the noise levels in the NICU (Matook et al., 2010).

Additionally, the majority of studies have focused on identifying the sources of noise in each NICU and have found that the major sources of noise contributing to the high noise levels were alarms of devices and human-related sources of noise (Laroche & Fournier, 1999; Nathan, Tuomi & Müller, 2008, Valizadeh at el., 2013, Fortes-Garrido et al., 2014, Neille et al., 2014, Romeu et al., 2016, Joshi & Tada, 2016, Carvalhais et al., 2016). The human-related sources of noise include, human vocalisations (staff conversations, crying babies, coughing), and object noises (closing of doors, dropping of objects, radio, ringing telephone, wheeling of trolleys, ventilator) (Laroche & Fournier, 1999).

The predominance of noise from alarms and human-related sources have resulted in high noise levels in the mid and high frequency range in the NICU, which is of great concern, because of the vulnerability of the preterm neonate's cochlea to such frequencies (Livera et al., 2008; Lahav & Skoe, 2014, Konkani & Oakley, 2012). A review of the research indicates that the majority of studies, as well as existing recommendations have focused on intensity of the noise levels, rather than the frequency content of noise in NICU, leaving the problem of excessive exposure to mid and high frequency noise largely overlooked (Knutson, 2012; Lahav & Skoe, 2014).

The present study determined the frequency content of noise, to understand their impact in the NICU, which may add to existing literature. Additionally, the lack of data regarding noise levels in NICUs in the South African context warrants further research (Neille et al., 2014). Existing studies, especially in South Africa, have short measurement periods, which could have resulted in certain sources of noise being overlooked. The present study aimed to identify the noise levels and conduct direct observations to identify the sources of the noise in the NICU that may be contextually relevant to South African hospitals. Findings may guide health care professionals affiliated with the NICU in establishing noise assessments and monitoring protocols, as well as education and training programs, which may facilitate a cultural shift towards a quieter and less stressful environment (Neille et al., 2014; Carvalhais et al., 2016; Ahamed, Campbell, Horan & Rosen, 2017; Ramm et al., 2017).

Noise in the NICU can cause multiple stressful events that forces the preterm neonate to expend a significant amount of energy to mediate its effects (Smith et al., 2018). The goal should be to remove as many of these stressors as possible, so that the neonate can reserve their energy for healing. To accomplish this, attention must be given to identifying the sources of noise in the NICU that can be reduced before noise reaches the neonate. Hence, the study was informed by a simple systematic approach to noise control (the source-path-receiver model) (Brown & van Kamp, 2017; Crocker, 2018), which will be discussed further in chapter two.

The model may guide the study in identifying areas that requires intervention to provide the best practice in the NICU. Identification of the noise levels and key sources of noise that contribute to the noise from the start until it reaches the neonate may be the foundation to create a safe and healing acoustic environment in the NICU. Therefore, the research question is 'What are the noise levels and contributing factors to the high noise level in NICUs within the public sector in the eThekwini District?'

1.3 Outline of Chapters

Chapter 1. Introduction: This chapter focused on the study problem, highlighting the presence of high noise levels and effects on the vulnerable neonate in the NICU. Important findings where mentioned that have implications for the present study, which led to the rationale and the research question of the study, as well as the aim and objectives of the study.

Chapter 2. Theoretical background: The historical background of the model used to inform the study that is the source-path-receiver model was discussed in this chapter. Important concepts that are commonly used in noise studies were discussed in detail to be able to understand subsequent chapters of the study. This chapter also reviews local and international literature relating to noise studies conducted in NICUs.

Chapter 3. Methodology: Chapter three outlines the methods used to conduct the study and describes the research tools and analysis for each of the objectives. It includes the reliability, validity and ethical considerations that were undertaken in the study.

Chapter 4. Results: This chapter presents the findings of the study in accordance with the objectives. Results are displayed on tables and bar graphs, as well as figures are used to illustrate the changes in noise levels associated with the presence of a noise source and the frequency content of noise levels during the morning, afternoon and night and on a week day and weekend.

Chapter 5. Discussion: Chapter five discusses the study results and interprets them with respect to the results obtained in previous studies. The present study results and associated noise control strategies are highlighted in relation to the source-path-receiver model.

Chapter 6. Conclusion: Chapter six establishes the extent to which the aim was achieved by revisiting the results for the objectives and indicates the significance and limitations, as well as practical and research implications of the study.

Chapter 2. Theoretical framework and Literature review

2.1 Introduction

This chapter provides an overview of the theoretical framework of the study, and relevant concepts that are associated with conducting noise measurements in the NICU. The effects of noise on the neonate, as well as a review of relevant findings from previous literature on noise in the NICU will also be discussed in this chapter.

2.2 Theoretical framework

The present study used the source-path-receiver model to inform the investigation of noise levels and contributing factors to noise in the NICU. The source-path-receiver model is a simple yet systematic approach to noise problems and was proposed by Bolt and Ingard in 1957, and many other researchers since that time, however one can find references to such system approaches more than 50 years ago (Dunn, Hartmann, Campbell & Fletcher, 2015, Crocker, 2018). The model assesses the risk of noise in the environment, by considering the characteristics of noise from the source, factors that may contribute to the noise levels along the path and finally the effect of noise on the receiver, which in this study are the neonates.

Investigating and controlling noise in an environmental context like the NICU may be difficult due to the diversity of noise sources, therefore this model is applicable to the present study as it provides a systematic approach in investigating various sources of noise, which may have implications for intervention. Figure 2.1 presents the source-path-receiver model which consists of three stages, the first stage is identification and control of noise at the source - if noise at the source cannot be eliminated or reduced, the transmission path should be assessed.

Transmission refers to the propagation of sound through air, and the transmission path is the route from the source to the receiver (Crocker, 2018).

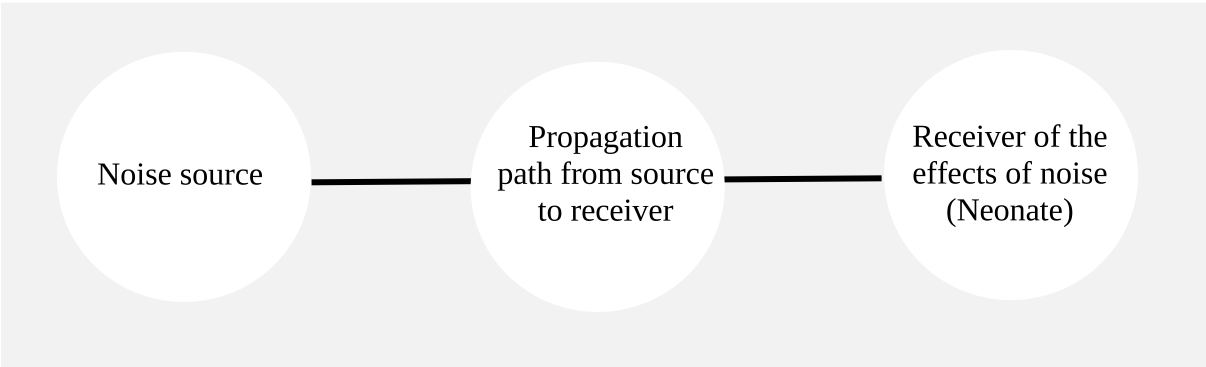

Figure 2.1. Source-Path-Receiver Model.

Often the path from the source to the receiver is not a straight line, with multiple paths that occur when sound reflects from hard surfaces along the path such as the floor, windows, doors, machines, and table-tops (Evans & Philbin, 2000). Any noise generated in the NICU gets reflected and re-reflected till it loses its energy, which is called reverberation (Livera et al., 2008). Research has found that NICUs are extremely reverberant environments and it is likely that reverberation contributes to the noise level to a significant degree (Nathan et al., 2008; Matook et al., 2010).

Treating surfaces with absorptive materials can potentially reduce reverberation in the NICU (Nathan et al., 2008), as well as introducing acoustical barriers, enclosures and high partitions in the NICU can control the noise along the transmission path before it reaches the neonate (Behar, Chasin & Cheesman, 2000). Acoustical barriers act as a partial enclosure by interrupting the direct flow of noise energy (Behar et al., 2000). An acoustical enclosure is like a barrier, with the difference that the enclosure completely cuts the flow of energy to the surrounding space (Behar et al., 2000). The control of the sound transmission path, with acoustical barriers, enclosures, and surface treatments only addresses the symptoms of noise, whereas reducing noise at the source has proven to be the best and least expensive long-term noise control measure, because the cause is eliminated (Berger, Royster & Driscoll, 2003; Konkani & Oakley, 2012; Crocker, 2018). Therefore, this study focused on identifying and investigating the source of the problem, which may provide information on ways to reduce or eliminate the cause of the problem.

Additionally, the amount and type of noise reduction required in any setting is determined by conducting various steps and identifying various factors of the noise, which include measuring the intensity level of the noise, and considering factors such as the frequency content of noise, the time of day and the temporal pattern of the noise (Crocker, 2018). Therefore, the objectives of the present study were guided by the above concepts, which will be discussed further to understand subsequent chapters of the study and to read technical literature in the field of noise and noise measurements.

2.2.1 Noise measurements.

The terms 'sound' and 'noise' have been used interchangeably in studies measuring noise levels in various environments (Matook et al., 2010). Sound is defined as an auditory sensation evoked by fluctuations in pressure within a medium that has elastic forces and viscosity (Berger et al., 2003; Matook et al., 2010; Rawool, 2011). Noise corresponds to an unwanted or undesired sound, which may be perceived differently by listeners (Dobie, 2015; Matook et al., 2010; Crawford, 2016). The effects of noise on the auditory system does not depend on its desirability but rather on the nature of the noise, that is the acoustic intensity, the temporal pattern of the noise and duration and the frequency content of the noise (Berger et al., 2003; Crawford, 2016; Almadhoob & Ohlsson, 2015).

The main instruments used to measure the nature of the noise, are dosimeters and sound level meters (SLM) (Gelfand, 2009; Rawool, 2011). The dosimeter continually monitors and records noise that an individual is exposed to and calculates the daily noise dosage (Rawool, 2011). An integrated type two SLM has been used in the majority of studies that measured noise in the NICU and is the preferred instrument to use to obtain the average level of noise in the environment, hence a type two SLM was used in the present study (Gelfand, 2009; Cohn, 2018). The SLM measures the intensity of sound pressure levels which is represented as decibels (dB) (Berger et al., 2003). The range of sound pressure levels that human listeners can detect is very wide, therefore noise levels are measured on a logarithmic scale, with 0dB being the threshold for human hearing (Darbyshire & Young, 2013; Stafford, Haverland & Bridges., 2014).

In addition to the intensity of noise, the human ear can respond to a range of frequencies which is measured in Hertz (Hz) ranging from 20 to 20 000Hz, depending on the hearing sensitivity of the person (Behar et al., 2000). Frequencies lower than 20Hz are called infrasounds and are difficult for the human ear to detect, frequencies approximately between 500Hz to 5000Hz are speech frequencies, and frequencies much higher than 20 000Hz are known as ultrasounds and can only be detected by some animals (Behar et al., 2000; Commonwealth of Australia, 2004).

The range of frequencies are categorized according to three broad categories (low, mid and high), however their specific start and cut of points are not universally accepted (Commonwealth of Australia, 2004; Konkani & Oakley, 2012). Leventhall (2004) refers to low frequencies as the range from approximately 10 to 200Hz and Stach (2003) indicates that high frequencies are above approximately 2000Hz. Given the definitions of low and high frequencies, the present study considered frequencies below 200Hz as low frequencies, mid frequencies as levels between 200Hz and 2000Hz and high frequencies as levels above 2000Hz (Commonwealth of Australia, 2004).

The human ear is sensitive to frequencies in the mid-range or speech frequency range, so to accurately approximate the sensitivity of the human hearing system an A-weighted sound level (dBA) is used to measure noise levels with the SLM (Gelfand, 2009). The A-weighted filter is the mandatory and the most commonly used filter, which focuses on the mid and high frequency ranges that humans hear and gives less emphasis to low frequencies to which hearing is less sensitive (Gelfand, 2009; Gray & Philbin, 2000; Padmakumar, Bhasin, Wenham & Bodenham, 2013). Other weighting networks, includes the C-weighting network, which approximates a linear response (Gelfand, 2009).

The International Electrotechnical Commission (IEC) 61672 standard introduced a new optional Z (or zero) weighing as a replacement for linear or flat weighting networks (Narang & Bell, 2008). Impulses or peak values with significant frequency components will not produce different readings between A and C weightings, therefore the Z-weighting network will be used in the present study to represent peak values, as it an unweighted network and has been used in previous studies measuring peak noise in the NICU (Berger et al., 2003; Valizadeh et al., 2013; Lahav, 2015).

Additionally, to accurately capture all characteristics of the noise, the noise measurements in the present study were conducted using various noise metrics that included LAeq, LAmin, LAmax and LZpeak. LAeq is the equivalent level, which integrates the noise levels into a single number that summarizes the overall level of exposure 'averaged' over time (Gelfand, 2009). It is important to conduct LAeq measurements in the NICU to evaluate the average noise level to which the neonate is exposed to during their stay in the NICU. LAmax is the maximum variation of noise levels over a period whereas LZpeak is the highest sound level reached, no matter how brief the duration (Stafford et al., 2014; Crawford, 2016; Cohn, 2018).

Often, LAmax is confused with LZpeak when describing extremely high noise levels, but there is a difference between them (Stafford et al., 2014; Crawford, 2016). LAmax is the maximum variation of noise levels over a period whereas LZpeak is the highest sound level reached, no matter how brief the period (Stafford et al., 2014; Crawford, 2016; Cohn, 2018). The energy that causes a peak can be so brief that a person would not have perceived the sound as been so high, hence the LZpeak will often be greater than LAmax (Gray & Philbin, 2000).

The LAmax should be recorded to capture loud sounds that can be hidden if integrated over a time (Crawford, 2016). It is also important to measure LZpeak values in the NICU, because their value may provide additional information on the effects of noise on the neonate. Sudden high noise levels can cause the most amount of stress to the neonate and result in mechanical damage to the hair cells in the cochlea due to their excessive intensity (Laroche & Fournier, 1999; Li & Steyger, 2009, Lahav, 2015).

Additionally, measuring the LAeq, LAmax and LZpeak, were specifically important for the present study, as the findings may provide additional information on the effect that a source can have on the noise level. When the intensity of the noise source is loud enough, it can cause a concurrent change in the measurement levels of the LAeq, LAmax and LZpeak, which may allow the researcher to identify the loudest noise sources in the NICU. Identifying associations between the LAeq and LZpeak measurements, can also provide information on the average highest noise level to which the neonate is exposed to during their stay, as well as additional information on the types of noises in the NICU.

The types of noises are classified in their temporal patterns as continuous, that is if the noise level remains above the level of effective quiet, which is the level that is quiet enough so that it does not cause auditory damage (Gelfand, 2009), whereas transient noise is sudden and have a higher intensity (Gelfand, 2009; Li & Steyger, 2009; Rawool, 2011). LAeq measurements are associated with identifying continuous noise sources, while LZpeak measurements are associated with identifying transient noise sources. Impact noise are transients and are created by collision of objects with a resultant high intensity peak usually less than 140dB, while impulse noise usually exceeds 140dB (Dobie, 2015).

The NICU has a variety of types of noise, including both continuous and transient, which may have differing effects on the auditory system. In the NICU, the intensity of a transient noise which is seen in the LZpeak measurements are caused by alarms, closing metal bins and dropping objects (Valizadeh et al., 2013, Lejuene et al., 2016). Infant cries and conversations can be regarded as continuous noise, which contribute greatly to the overall noise level (Laroche & Fournier, 1999). Both transient and continuous noise can result in temporary and often permanent hearing loss (Laroche & Fournier, 1999; Li & Steyger, 2009).

A temporary or permanent hearing loss depends on the intensity and the duration of the noise (Gelfand, 2009). The hair cells can be damaged and repaired if the hairs cells have a period of rest, which is called a temporary threshold shift, or after longer and repeatable exposures to noise the hair cells can completely collapse, which results in a permanent threshold shift (Katz, Medwestsky, Burkurd & Hood, 2009). Therefore, the duration of exposure and intensity of the noise is a key indicator on the extent of damage to the auditory system. The present study considered the effect of duration on the auditory system by measuring the noise levels for 24 hours, to determine the intensity of noise the neonate is exposed to for their length of stay in the NICU. However, researchers have specified that an assessment of noise based on only the intensity of noise may be inadequate, as noise at low intensities have also shown to have physiological effects on the neonate (Livera et al., 2008; Prashanth & Venugopalachar, 2011; Lahav & Skoe, 2014).

An efficient evaluation of the noise requires a frequency spectrum analysis, which may yield more insight when identifying adverse health effects, and the extent of auditory damage (Prashanth & Venugopalachar, 2011). It is important to understand the spectral qualities of the sources of noise in the NICU to be able to reduce the effect of the offending frequencies (Konkani & Oakley, 2012), hence the present study conducted a frequency analysis of the noise using one-third octave bands to determine whether low, mid or high frequencies dominate the NICU environment.

Octave band analysis separates a noise or signal into its component frequencies, and one-third octave band analysis provides a finer picture of the frequency content (Gelfand, 2009). Octave bands are a way of looking at general trends in noise that may vary considerably from instant to instant (Gray & Philbin, 2000). It provides detail characteristics of the low-mid and high frequencies in the noise so that noise sources in the background can be easily identified (Berger et al., 2003). The sources of low frequency noise in the ICU setting are mainly a resultant of the ventilation systems, while other sources can be either natural (wind, air turbulence) or artificial (heating, air conditioning and speakers) (Siebein, Skelton, McCloud, Lilkendey & Paek, 2009; Konkani & Oakley, 2012). Low frequency noise can be generated from facility noise which exist in an empty building when it is constructed such as air passing through ducts and supply diffusers (Evans & Philbin, 2000; Siebein et al., 2009). Other facility noise includes velocity in turbulence ducts that generate mid frequency noise, and exhaust and supply air diffusers that generate high frequency noise (Evans & Philbin, 2000).

The sources of noise that exist in an occupied NICU, which is known as operational noise include low frequency noise mostly from ventilator machines (Lejuene et al., 2016; Konkani & Oakley, 2012), mid frequency noise from human voice, such as staff conversations, and high frequency noise mainly occurring from alarms of devices, telephones, vacuum cleaners and dropping objects (Livera et al., 2008; Nogueira, Di Peiro, Ramos, Souza, & Dutra, 2011; Lahav & Skoe, 2014; Lejeune et al., 2016; Cohn, 2018). Despite differing beliefs, the majority of the literature indicate that mid and high frequency noise dominate the NICU, with the highest noise levels observed in the 1000 to 8000Hz (Livera et al., 2008) and the 501 to 3150Hz (Lahav & Skoe, 2014) frequency ranges.

The dominance of mid and high frequency noise in the NICU is concerning especially for the preterm neonate, as mid and high frequency discrimination, which occur in the cochlea of the inner ear are most vulnerable to damage due to the way the cochlea is developed (Konkani & Oakley, 2012; Lahav & Skoe, 2014). The cochlea is a spiral snail shape and evolved to conserve space in the skull and to increase the octave band range (Dobie, 2015). The hair cells found on the basilar membrane of the cochlea are tonotopically organised, to segregate sounds of different frequency content so that the listener can recognise complex sounds based on the frequencies present (Dobie, 2015; Lahav & Skoe, 2014).

Figure 2.2 is an illustration of the shape of the cochlea and the positions of different frequencies. Gradual development of tonotopic frequency maps occur with the low frequency regions maturing first before high frequency ones, a process referred to as frequency-dependent plasticity (Lahav & Skoe, 2014). Frequency dependent plasticity is associated with the makeup of the womb, which consist initially of low frequencies, such as those generated by the mother's internal organs that stimulate the development of cells in the apex region (green shaded area) (Picciolini et al., 2014, Lahav & Skoe, 2014).

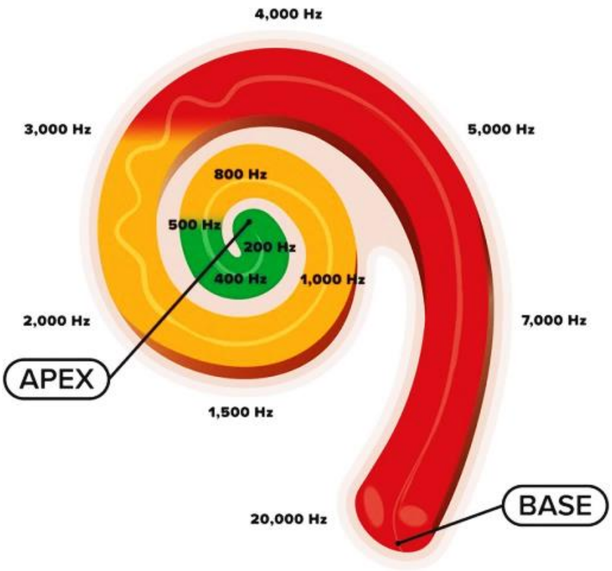

Figure 2.2. The tonotopic organisation of frequencies in the cochlea. Source: An illustration of the cochlea and its tonotopic development across the frequency spectrum by Lahav and Skoe (2014), *Front. Neurosci. 8:381*. Copyright 2014 by Lahav and Skoe. Reprinted with permission.

As the foetus grows the uterine wall thins allowing higher frequency sounds to penetrate the womb, for the development of high frequency hair cells in the basal end of the cochlea (red shaded area) (Picciolini et al., 2014; Lahav & Skoe, 2014; Mankse, 2017) (Figure 2.2). In the womb the neonate is exposed to sounds predominantly in the low frequency region, but in the NICU the neonate is exposed to sounds across all the frequency areas of the cochlea (Lahav &

Skoe, 2014). Therefore, the cochlea of neonate's may only have fully developed hair cells in the low frequency area when admitted to the NICU and may be ill prepared to process other frequencies (McMahon et al., 2012; Lahav & Skoe, 2014, Venkataraman et al., 2018). The above evidence has implications for the present study and highlights the importance of measuring the frequency content of noise in the NICU. The last stage of the source-path-receiver model, highlights the importance of identifying the effects of noise on the receiver, which will now be discussed. Table 2.2, presents a summary of the auditory developmental milestones, which was developed by the researcher from previous studies, to understand the adverse effects of noise on the neonate.

Table 2.2

Auditory Developmental Milestones of the Foetus and Neonate

Auditory development milestones	**Gestational Age**
The auditory system including the cochlea is formed and anatomically functional (Cohn, 2018; Thakur et al., 2016; McMahon et al., 2012) Sounds in the womb are transmitted as vibrations through the contents of the head and the fluid chambers in the inner ear by way of bone conduction (Picciolini et al., 2014).	20-25 weeks
The foetus can perceive and reacts to auditory information (McMahon et al., 2012; Rand & Lahav, 2014; Picciolini et al., 2014).	25-26 weeks
Tonotopic columns are formed in the cochlea, which are essential for developing complex language and music skills (Venkataraman et al., 2018). Hair cells in the cochlea undergo fine tuning for frequency discrimination starting from low to high frequency (Rand & Lahay, 2014; Manske, 2017; Venkataraman et al., 2018).	26-30 weeks
Foetus can learn and discriminate between voices and has auditory memory involving speech and musical sounds with frequencies less than 250Hz (Graven, 2000; Venkataraman et al., 2018).	30 weeks
Foetus can differentiate their mothers voice from other voices, as shown in changes of heart rate (Rand & Lahav, 2014).	32 weeks
Neonates can differentiate emotional qualities of speech, music and moods which are stored as auditory memories (Venkataraman et al., 2018).	34-35 weeks

The neonate's auditory system is developed and functional from 20-25 weeks of gestational age, therefore unless there is a congenital abnormality, most preterm neonates can hear when admitted to the NICU (McMahon et al., 2012). Research indicates that sudden high noises may startle the neonate, which could result in adverse physiological effects (McMahon et al., 2012; Thakur et al., 2016; DeArmond et al., 2016; Joshi & Tada, 2016; Cohn, 2018, Venkataraman et al., 2018). A sudden response to the noise has found to excite the subcortical systems and the automatic nervous system, which raises cortisol levels and lowers the immunity of the neonate (Carvalhais, Silva, Silva, Xavier, Santos, 2018; Venkataraman et al., 2018).

Additionally, high noise levels can result in apnoea, bradycardia, increased intracranial pressure, hypoxia, attention deficit and sleep disorders (Carvalhais et al., 2018). Sleep disorders in the NICU can be due to routine monitoring and exposure to excessive light and noise, which often disturbs the neonate from their natural sleep cycle (Venkataraman et al., 2018). Rapid eye movements (REM) seen in natural sleep aids in the formation of long-term synapses in the auditory cortex, which facilitates learning, making it essential that the neonate's sleep cycle remains undisturbed (Venkataraman et al., 2018). Interrupted sleep caused by noise may also result in induced stress, which activates the hypothalamic pituitary axis and causes growth inhibiting factors and loss of weight (Almadhoob & Ohlsson, 2015). Therefore, high noise levels should be reduced to increase the capacity of critically ill neonates to cope with the unexpected transition from the protective uterine environment to the NICU (Sinha & Kumar, 2018).

The uterine environment is said to be protective because maternal tissue and fluid protect the foetus from intense sounds outside the womb, which can potentially disrupt and damage the cochlea and in turn affect language development (Cohn, 2018). Preterm neonates have immature auditory systems, as the hair cells in the cochlea are still in the process of differentiation and the development of the auditory pathways is not complete as the hair cells are still undergoing the process of fine tuning till 35 weeks of gestational age (Almadhoob & Ohlsson, 2015). Therefore, during this critical period for auditory development, the presence of high noise levels may potentially disrupt the development and functioning of important auditory processes, which may hinder subsequent language development (Lahav, 2015)

Research emphasises that the first few months are a critical period for neural development, and lack of sufficient opportunities to perceive auditory information, especially the maternal voice, can alter the neonate's brain structure (Rand & Lahav, 2014; Picciolini et al., 2014; Filippa et al., 2017). The fact that neonates show a clear preference for their mother's voice within hours after birth can be taken as evidence that auditory memory begins while in the womb. Neonates not only seem to prefer their mother's voice over an unknown female voice, but they also prefer their native language (Filippa et al., 2017).

Exposure to the maternal voice can significantly provide physiological stability and improve weight gain and feeding tolerance in the early stages of life (Rand & Lahav, 2014; DeArmond et al., 2016). Additionally, the mothers voice that is familiar to the neonate helps in eventual language acquisition (Venkataraman et al., 2018). It is therefore important that exposure to the maternal voice, and other auditory stimulation is optimized in the NICU to facilitate appropriate language development (Sinha & Kumar, 2018; Ramm et al., 2017). Due to the high background noise in the NICU, the maternal voice, as well as other speech stimuli, are often distorted when it reaches the neonate's ear (Rand & Lahav, 2014). Therefore, the neonate may have opportunities to develop basic auditory abilities in the NICU but not necessarily meaningful language stimulation (Rand & Lahav, 2014).

Early language stimulation is important, as it is found to be associated with better cognitive and language outcomes later in life (Filippa et al., 2017). In the absence of a known brain injury, approximately 25-30% of preterm neonate's experience difficulties in language acquisition, which presents as behavioural and emotional problems, poor social relationships, poor verbal comprehension and attention deficits at school age (Milgrom et al., 2013; Rand & Lahav, 2014). Therefore, it is plausible that the lack of sufficient opportunities to perceive speech sounds during the NICU hospitalization can alter the brain structure and subsequently account for developmental problems later in life (McMahon et al., 2012; Lahav, 2015).

In addition to the likelihood of poor speech and language development in preterm neonates, they are also more susceptible to developing a hearing loss (Nathan et al., 2018; Neille et al., 2014; Nair, Das & Soundararajan, 2018, Cohn, 2018). The incidence of moderate and severe bilateral hearing loss is estimated at two to four cases of every 100 neonates in the NICU, which is much higher than the lower risk population in well baby nurseries with a prevalence of two to three cases per 1000 births (Wroblewska-Senuik, Greczka, Dabrowski, Szyfter-Harris & Mazela, 2017; Cohn, 2018, Nair et al., 2018).

Risk factors for hearing loss among preterm neonates include the administration of ototoxic drugs (aminoglycosides), presence of hyperbilirubinemia, hypoxia and noise exposure (Wroblewska-Senuik et al., 2017; Nair et al., 2018). Similarly, Li and Steyger (2009) found that very preterm neonates (born before 27 weeks) in the NICU, and those who received aminoglycosides for seven days or more while exposed to noise levels had a high probability (68%) of developing a hearing loss. Neonates receiving aminoglycosides were found to have toxic reactions in the inner ear in combination with loud noise (Li & Steyger, 2009; Zimmerman & Lahav, 2013; Ramm et al., 2017, Cohn, 2018). As neonates in the NICU present with multiple risk factors for hearing loss, it is difficult to specify which could be the cause, however the presence of high noise levels only increases the odds (Cohn, 2018; Wroblewska-Senuik et al., 2017). Additionally, the prevalence of risk factors to hearing loss cannot be generalised and are likely to vary from country to country. The Joint Committee on Infant Hearing (JCIH) position statement provides a list of risk factors recommended for use in risk-based screening and has specified that malaria and maternal Human Immunodeficiency Virus (HIV) are contextual risk indicators in South Africa (Health Professionals Council of South Africa [HPCSA], 2018).

A local study found that two participants were HIV exposed in the NICU, and that ototoxic medication was administered to eight out of the 11 participants, which included amikacin, and vancomycin, with gentamycin been the most frequently administered drug (Kanji & Khoza-Shangase, 2016). Another local study found that in a tertiary hospital in Gauteng, the most frequently occurring risk factors for hearing loss were prematurity (98,83%), neonatal jaundice (88,37%), exposure to HIV (17,44%), NICU stay for longer than 48 hours (15,11%), mechanical ventilation (15,11%) and exposure to ototoxic medication (10,46%) (Kanji & Khoza-Shangase, 2012). The high occurrence of multiple risk factors for hearing loss seen in preterm neonates emphasizes the need for investigating and reducing noise in the NICU.

2.3 Literature Review

Despite the large amount of evidence indicating the importance of reducing noise in the NICU, an historical summary of the literature clearly indicates that the noise levels in NICUs, and the sources of noise, are the same that it was decades ago. A summary of previous research findings on noise in the NICU are shown in Table 2.3.

Table 2.3

A Historical Review of Literature on Noise in the NICU

Authors, Year Location	**Objectives and methodology**	**Findings, Recommendations and Limitations**
Laroche and Fournier (1999) Eastern Ontario	To measure noise levels using SLM and observe noise sources and their LAeq and frequency of occurrence. **Measurement period:** 24 hours **Measurement location:** The SLM was positioned one metre from the neonate's head and ceiling measurements.	LAeq level was highest in the evening (57dBA), followed by the day (50dBA) and night (45dBA). Alarms, human vocalisations and objects noise contributed the most to the noise levels. There were no differences in noise level between day and evening. The results can be used in a training session to determine if the noise levels decrease post intervention.
Nathan et al. (2008) Tygerberg Children's Hospital NICU South Africa	To measure noise levels and the frequency of occurrence of noise sources using a checklist and to measure sound decay. **Measurement period**: 12 hours (8h00-20h00) on two weekdays **Measurement location:** Central site procedure, SLM positioned on the ceiling	Noise levels ranged from 62,3-66,7dBA. The study did not measure noise levels during the night. Frequency of occurrence- Conversations (27.8-36,0%) and alarms (23.7-28.7%) occurred the most frequently. The level of noise was affected by reverberant noise. Future research should assess the design of NICUs and their compliance to the standard and evaluate existing noise reduction strategies in South African NICUs.
Livera et al. (2008) Level III NICU Bangalore, India	To perform a spectral analysis of the noise sources **Measurement period:** 15 days **Measurement location:** Central site procedure, SLM positioned on the floor The nurses were trained to take measurements	Spectral analysis showed high level of noise in the high frequency range. Equipment and activities (1000-8000Hz) Ventilators and nebulisers (500Hz) A limitation was that caregivers were aware of the measurements been taken which could have influenced their behaviour.
Matook et al. (2010) Level III NICU United States, New England	To identify time periods and areas that have high noise levels. **Measurement period:** 24 hours over three months, Day shifts (7h00-19h00) and Night shift (19h00-7h00) **Measurement location:** SLM which was in a box and placed in an unknown place in the NICU	LAeqs ranged from 49.5-89.5dB with the highest been 89.5dB in the middle bay. Reverberation plays a role in noise levels. The day shift was significantly higher than night shift, during shift changes and on Wednesdays. The limitations of the study were that all sources of noise could not be identified and measured, and that the facility noise was not measured, which could serve as a baseline.

Knutson *(2012)* *Level III* *United States*	To conduct sound surveys in the NICU and the incubator and compare them to the 45dBA recommendation. **Measurement period:** Recorded for 20-30 seconds and for a period of 24 hours, Day (12 hours) Night (12 hours) **Measurement location:** Inside the incubator and in a private room	The day level was 3dB within the night level. The range of NICU levels were from 48-55dB and incubator levels were 58-71dBA. The noise level in the incubator increased to 58dB due to improper closing of the porthole. Future research should look at the physiological effects of noise to justify the 45dB recommendation and should look at Level I and Level II NICUs to find comparisons.
Valizadeh et al. *(2013)* *Al-Zahra teaching hospital NICU* *Iran*	To assess noise levels and determine sources of noise. **Measurement period:** 24 randomly selected hours for four days from 7h00-22h00 **Measurement location:** At the centre of six locations, SLM positioned on the floor	There were no significant differences in the noise levels between the six locations in the NICU. The mean LAeq was 63,46dBA. Nursing rounds were the noisiest time in the NICU. The noise level was lowest at 22h00. A limitation was that the nurses were aware of the SLM, therefore future studies should consider hiding the SLM. The results can be used in the development of noise control policies.
Fortes-Garrido et al. *(2014)* *Medium Size Public Neonatal ward* *Huelva, Spain*	To assess and characterise noise levels in the NICU. **Measurement period:** 15 days **Measurement location:** SLM attached to a central beam on the ceiling and another was placed in an incubator	The critical care ward LAeq levels were 4.0dB higher than the intermediate ward. The highest LAeq was seen during shift changes, nursing and feeding times. The noise in the incubator was lower (54dBA) than out (62dBA). Afternoon noise levels were significantly higher than mornings due to visiting hours.
Neille et al. *(2014)* *NICUs private hospitals and one tertiary level public hospital in Gautang* *South Africa*	To identify sources of noise greater than 45dBA, and to identify the noise at different positions in the NICU. **Measurement period:** Three consecutive days at four times in the day **Measurement location:** Inside the incubator next to the neonate's head	All noise sources greater than 45dBA was human generated except for a high frequency ventilator. Sound levels were 88.4dBA in the incubator. The limitations were that the NICU environment did not remain constant and readings were taken for a short amount of time. The SLM was also placed in the incubator, where reverberation could have influenced the results. Future research should replicate the study with a larger sample size and monitor physiological effects of noise.
Jahangir Blourchian and Sharafi *(2015)* *Al Zahra teaching hospital NICU* *Iran*	To determine noise levels and sources of noise. **Measurement period:** Morning, afternoon and night over a week **Measurement location:** The SLM was placed one meter away from the noise equipment.	There were no significant differences in the noise level with the devices turned on and off in the three shifts (p=0,435). Cell-phone ringing in one metre distance (85dB) and neonatal crying (81dB) caused the highest noise. The results can be used to raise awareness by providing educational preparation for personnel.

Joshi and Tada (2016) *Tertiary Level III hospital NICU and postnatal ward* *India*	To identify noise levels and noise sources. **Measurement period:** 24 hours, total of 504 hours, in the Morning (8h00-14h00), afternoon (14h00-20h00), evening (20h00-8h00) **Measurement location:** SLM was in the middle of four cubicle areas	The morning shift had the highest mean LAeq (77.89dB) followed by the afternoon (73,30dB) and evening (69.11dB). Alarms and noise from conversations generated the most noise. Despite absence of equipment in the postnatal ward, noise levels were also high. It is recommended that proper protocol should be designed to detect noise sources.
Gallo and Olivera (2014) *Level three hospital* *Argentina*	To develop and maintain a system which addresses technological, management and training aspects to monitor and control noise in NICUs **Measurement period:** 24 hours on three days Non-participatory observations-initial reconnaissance observations and during noise measurements **Measurement location:** SLM was placed 1,20 m above the floor close to the incubator	Noise levels were between 62,5dBA and 64,6dBA and maximum values were between 86,1dBA and 89,7dBA. Highest noise levels were seen on Monday from 7h00-12h00. Noise sources with the highest occurrence was alarms (25,16%) and loud staff speaking (18,90%). Raising awareness through continuous training programs and creating a collaborative working environment where behaviours can be imitated is vital. It was necessary for the researcher to be present to identify sources of noise and their occurrences to apply an expert judgement. Staff should also be informed about the study to generate a cooperative environment and avoid alterations in staff behaviour.
Ramm et al. (2017) *Level six hospital NICU* *Australia*	To compare noise levels in an open plan NICU design versus pod design **Measurement period:** Four weeks **Measurement location:** A dosimeter was placed in each room above a sink Observations were done independently by two researchers during low and peak periods	Mean noise levels in the NICU was 48,99773dB and in the pod was 47.29533dB. The nosiest time was during nursing handover. Isolated peaks reached 74.5dB in the NICU and 75.9dB in the pod due to alarms, ward rounds, conversations, and neonate crying. More research should look at interventions to reduce noise and to ascertain if staff can work quieter in pods to allow for more family centred benefits.
Carvalhais, Silva, Xavier and Santos (2017) *North Portugal*	To measure noise levels during several health care activities **Measurement period:** Five to 10-minute measurements per set of tasks **Measurement location:** Inside the incubator near the neonate's ear	No significant differences were found between task and NICUs. Monitoring vital signs and drawing blood generated the most noise. Closing the porthole doors incorrectly increased the noise level in the incubator. Awareness and training sessions should be implemented to minimize noise activities generated by health care staff.

Consistently high noise levels were found to be present during the morning in most of the studies (Matook et al., 2010; Valizadeh et al., 2013; Fortes-Garrido et al., 2014; Joshi & Tada, 2016; Carvalhais et al., 2016; Cohn, 2018). The reason for the higher noise levels in the morning include the presence of staff rounds, care-giving, cleaning of rooms, infant cries that set of more alarms and the presence of conversations between staff (Laroche & Fournier, 1999, Nathan et al., 2008; Carvalhais et al., 2016).

Fluctuating sound levels during the evening were usually due to excessive conversations during shift changes, and treatment of infants which resulted in infant cries, that set-off of alarms (Laroche & Fournier, 1999). Infant cries and warning alarms seemed to have caused sound variations in the night shift (Laroche & Fournier, 1999), whereas fewer visitors, health professionals and low lighting, has shown to reduce conversation during the night, and subsequently the level of noise (Carvalhais et al., 2016; Matook et al., 2010).

Although lower noise levels were found during the night and higher noise levels in the morning, there are controversial views on whether there are associations between the time of day and the high noise levels. Significant differences have been found between the morning and night shift ($p < 0.05$), and between the afternoon and night shift ($p < 0.05$), but no significant differences were found between the morning and afternoon shift ($p = 0.369$) (Carvalhais et al., 2016). Additionally, Joshi and Tada (2016) found that noise levels between the morning, afternoon and night shift were statistically significant, with the levels decreasing after the morning shift (77.89dB) to the night (69.11dB).

Alternatively, Knutson (2012) found that day and night levels revealed no significant differences, as all night levels were within 3 dB of the day levels. Nathan et al. (2008), did not conduct measurements at night due to the lack of differences between the morning and night shift seen in previous studies, which may limit generalizations to other local studies. Further investigation of the noise levels has shown that they are higher during specific days of the week, and higher on week days than on weekend days (Matook et al., 2010; Carvalhais et al., 2016). Carvalhais et al. (2016) found that noise levels are higher on Mondays than any other day of the week, and higher on week days than on weekends.

Similarly, Gallo and Olivera (2016) found that noise levels were highest on Mondays from 7h00 to 12h00, because of visits from specialists and conversations from physicians consulting about patients as well the presence of monitoring procedures. Whereas, Matook et al. (2010) found that Wednesdays have higher noise levels because of grand ward rounds and x-ray rounds. Controversial findings between the noise levels and different times of the day and day of the week may depend on the operations of each hospital, which may differ from NICU to NICU. Hence, it is important to identify noise levels during different time periods to be able to identify the loudest time of the day and week, which had implications for the present study as noise measurements were conducted in the present study during the morning afternoon and night and on a week day and weekend.

Additionally, researchers have found that weekly activities that contribute to the noise levels seem to vary with the time of day, especially when there are more care providers and treatment activities, denoting a significant human factor (Valizadeh et al., 2013; Fortes-Garrido et al., 2014; Ahamed et al., 2017; Cohn, 2018). The noisiest times were during ward rounds at 9h00 and 10h00, as well as during nursing handovers (Ramm et al., 2017). Similarly, the noise levels were higher at around 14h00 at the end of visiting hours and when staff was relying information to family members (Fortes-Garrido et al., 2014). Noise levels were found to increase when shift changes take place due to conversations (Matook et al., 2010; Fortes-Garrido et al., 2014). An increase in the noise levels is seen when staff start working at 8h00 and then again when they leave work (Fortes-Garrido et al., 2014). Furthermore, Valizadeh et al. (2013) found that the highest noise levels were seen during nursing rounds and had a direct relationship with the number of people in the ward (p=0,007). Nurses also showed the highest level of inattentiveness to alarms and crying babies during this time, which could have influenced the noise levels (Valizadeh et al., 2013).

Fortes-Garrido et al. (2014) also found that the noise levels reach its maximum when nursing and monitoring of neonates occur. The highest LCpeak level (111.2 dBA) was found when the nurses administer medication and provide hygiene and vital nutrients to the infant, and the highest LAeq levels were found when nurses were monitoring vital signs and drawing blood (Carvalhais et al., 2017). Researchers suggest that posters should be put up in the NICU to remind nurses about quiet treatment practices, and that facilities should develop guidelines and protocols for best treatment practices (Laroche & Fournier, 1999; Ramm et al., 2017). To implement changes, the nurses should be constantly aware of their behaviours and common sources of noise (Ahamed et al., 2017).

The common sources of noise include warning alarms (63dBA-68dBA), human vocalisations (64dBA-73dBA) and object noises (48dBA-75dBA) (Laroche & Fournier, 1999). The most occurring sources of noise were from a cardio monitor alarm which occurred every five minutes per hour, conversations occurred 38% of the time and ripping of tissue occurred 4,8 times per hour (Laroche & Fournier, 1999). Similar results have been found in recent studies measuring noise in the NICU, which indicate that the two major sources of noise are from alarms of devices and conversations (Nathan et al., 2008; Valizadeh et al., 2013; Neille et al., 2014;

Carvalhais et al., 2016; Joshi & Tada, 2016). Noise from alarms were present 75% of the time and increased the noise level to 80dBA (Romeu et al., 2016). Gallo and Olivera (2016) found that the frequency of occurrence of noise sources indicated that the majority of the noise was from alarms (25.16%), and staff speaking loudly (18.90%). Similarly found in another study, the most frequently occurring noise sources were alarms (28,7%) and staff conversations (36,0%) (Nathan et al., 2008).

Other sources of noise identified were washing dishes in metal sinks (67.75dBA), the presence of students (65.53dBA), nursing rounds (65.14dBA), physician rounds (65.05dBA), and wheeling trolleys (65.0dBA) (Valizadeh et al., 2013). Additionally, Jahangir Blourchian and Sharafi (2015) measured the nosiest sources at a one metre distance from the SLM and found that ringing of cell phones was 85dB, crying babies was 81dB, pager was 78dB, pulse oximetry alarm was 77dB and wheeling trolleys was 76dB. Valizadeh et al. (2013) found that falling objects occurred three times in the day and presented with the highest LZpeak level (90.0-110dB) which may result in the highest level of physiological instability in neonates due to its sudden occurrence.

Given previous results from various studies, it may be believable that the alarms of devices may increase the noise levels, however human related activities may contribute the most to the high noise levels found in the NICU. In support of this, Joshi and Tada (2016) found that the highest noise level in the postnatal ward was 79.20dB during the morning shift, which was surprising, as there were no instruments with alarm systems in the postnatal ward, despite which the noise levels were still high (Joshi & Tada, 2016). The high noise levels in the postnatal ward might have been due to number of beds, mother to child attendants and relative visits being allowed, as well as the presence of administrative and ward work (Joshi & Tada, 2016).

In agreement, Jahangir Blourchian and Sharafi (2015) found that in the NICU and neonatal wards there were no significant differences in the noise levels when the devices were turned off and on during the morning, afternoon and night shifts ($p=0.435$). Therefore, the findings suggest that, although alarms may increase the noise levels, it is unlikely that alarms are the main cause of high noise levels in the NICU. The beliefs in many NICUs are that noise is an unavoidable consequence of high technology and is a result of intensive care but previous research findings indicated that alarms of devices do not play a major role in the noise levels and that high noise levels may be primarily due to human-related noise sources, which can be effectively reduced or eliminated (Graven, 2000, D'Souza et al., 2015; DeArmond et al., 2016). Interventions that focus on reducing human-related noise, may include education, awareness and behavioural modification and consequently a change in culture can address most of the noise sources found in previous studies.

Ahamed et al. (2017) conducted an intervention protocol by raising awareness about the negative effects of noise on preterm neonates through targeted education, behavioural modifications and some environmental change (Ahamed et al., 2017). The baseline average noise level was noted to be 62.4dB and the peak level was 115dB (Ahamed et al., 2017). Post intervention, there was a gradual decline in both the average and peak noise levels. At the end of one year, the average noise levels had decreased to 56.0dB (10.1% decline) and peak level to 76dB. The study suggested that creating a culture change is possible, but it requires continuous dialogue between project managers and NICU staff (Ahamed et al., 2017).

Connor and Ortiz (2016) also used intervention approaches to combat high noise levels in response to low satisfaction scores obtained from in- hospital patients due to high noise levels. A vital part of the project was to teach nursing and ancillary staff about the effects of noise and the importance of noise reduction for patient healing. Sound level meters were placed in five locations and presented with a green light for acceptable noise levels and a yellow light for exceeding levels (Connor & Ortiz, 2016). Before staff education, the average noise levels reached 65dB, whereas after staff education the average readings decreased to 61.3dB, with readings being 56.1dB six months after education and training (Connor & Ortiz, 2016).

Noise levels in the hospital have shown to decrease post intervention and training but remain above the recommended standard. Similarly, Ramm et al. (2017) found that installing dB monitors in the NICU did not reduce the noise level lower than the recommended standard, making it necessary for staff to be informed about the importance of noise to facilitate behaviour change and thus a cultural shift. Good practice to control noise production in combination with ongoing training sessions of NICU staff, can be a possible starting point in providing an optimal NICU environment (Neille et al., 2014). Alternative social opportunities, as well as new expectations for appropriate NICU behaviour need to be developed during the change process.

2.4 Summary

The source-path-receiver model was described to systematically identify ways to reduce noise from the source before it reaches the vulnerable neonate. The nature of the noise, that is the acoustic intensity, temporal pattern and frequency content may provide valuable information in determining the extent of auditory damage. Noise is primarily measured using a SLM, which include functions to measure the LAeq, LAmin, LAmax and LZpeak. Measuring the LAeq and

LZpeak can be useful in identifying sources of noise, that may simultaneously influence the readings. In addition to measuring the intensity of noise, research indicate that determining the frequency content of noise in the NICU, may provide information that is needed to protect the neonate’s hearing. The octave band analysis function on the SLM, can measure the frequency content of noise, and a finer analysis of the content can be found by using one-third octave band analysis.

The frequency ranges can be analysed according to three categories, namely low (20-200Hz) mid (200-2000Hz) and high (2000Hz-20 000Hz). Research has found that the NICU consist mostly of mid-high frequencies, which is concerning due to the vulnerability of the preterm neonate’s cochlea to these frequencies. A historical overview of the literature has found that noise levels in the NICU are exceedingly loud, and various sources of noise, specifically human-related (conversations, shift changes, treatment activities, nursing rounds) and alarms may be contributory factors. Moreover, research has found that the time of day, as well as the day of the week influences the noise level, with the morning period and week days having the highest noise levels. Evidence suggest that training and behavioural modification should be implemented as a starting point in reducing the noise levels in NICUs.

Chapter 3. Methodology

3.1 Introduction

This chapter will present the aims, objectives and research design of the study. The inclusion and exclusion criteria, sampling method, data collection tools, adaptations of the pilot study, and the data collection procedure will be explained. Thereafter, an overview of the data analysis in accordance with each objective will be presented. The chapter concludes with reliability and validity considerations, as well as ethical considerations of the present study.

3.2 Aim

The aim of the study was to investigate noise levels in NICUs within the public sector in the eThekwini District. To achieve the aim, the following objectives were realized.

3.2.1 To measure and determine any significant differences between the noise levels during the morning, afternoon and night and on a weekday and weekend in each NICU.

3.2.2 To identify a sample of the sources of noise and their frequency of occurrence in each NICU.

3.2.3 To determine the frequency content of noise in each NICU.

3.3 Study design

The study adopted an analytic observational study design (Aparasu & Bentley, 2014). Analytical studies are aimed at understanding the relationship and/or causal mechanism that may exist between two or more variables (Aparasu & Bentley, 2014). It attempts to identify causes or risk factors that explain health related states or events (Merril, 2015). In analytical observational studies, researchers evaluate the strength of the relationship between an exposure and disease variables (Merril, 2015). This study design was appropriate for the present study, as the researcher aimed to capture repeated noise measurements under different conditions and to concurrently observe various sources of noise in each NICU. The results were then analysed to determine specific relationships between key variables such as the noise levels and sources of noise and, the frequency content of the noise and noise levels between the different times of the day, and days of the week.

3.4 Selection criteria

The present study included all public hospitals in the eThekwini district that had a fully functioning NICU, therefore hospitals without a fully functioning NICU were excluded to ensure that equipment and treatment variables remained consistent in each environment, and that reliable measurements were obtained. The NICU has different levels of care based primarily on availability of specialized equipment and staff, but many NICUs often consist of both intensive and intermediate care units such as high and low care units (White et al., 2013).

The AAP indicate that neonatal units consist of different levels of care, including level I, II, III and IV (Barfield et al., 2012). Units with Level I care includes well baby nurseries, which have nurses and paediatricians that provide postnatal care to stabilise preterm neonates until they are transferred to higher level care facilities (Barfield et al., 2012). Level II care includes level I professionals, paediatric hospitalist and neonatologist who treat preterm neonates and neonate's with low birth weight, who require mechanical ventilation for brief durations, until transferred to a neonatal intensive care facility (Barfield et al., 2012). Level III and IV care is found in a fully functioning NICU that includes the level II health care professionals, subspecialists and surgeons, providing care for all critically ill neonates and provides sustained life support, specialist paediatric services and advanced imaging (Barfield et al., 2012). A description of the selection criteria with motivations is presented in Table 3.1.

Table 3.1

A Description of the Inclusion and Exclusion Criteria and their Motivations

Selection criteria	**Motivation**
Inclusion criteria	
Public-sector hospitals in the eThekwini District that have a fully functioning NICU.	The public health sector was selected as it serves the majority (84%) of the population (Kanji & Khoza-Shangase, 2012). Additionally, limited resources, overcrowded treatment rooms, and poor structural design and acoustics commonly seen in public sector NICUs can contribute to the level of noise in these hospitals making it a critical site to investigate (Kanji & Khoza-Shangase, 2012; Botha, 2014; Kruger, 2014).
Public sector hospitals in the eThekwini District that are regional and/or tertiary level and that have a fully functioning NICU.	Regional and tertiary hospitals consist of a fully functioning NICU to fulfil the purposes of this study.
Exclusion criteria	
Public-sector hospitals in the eThekwini District that do not have a fully functioning NICU	The NICU treats the most critically ill neonates who are at a higher risk to the effects of noise (D'Souza et al., 2015; Thakur et al., 2016, Gallo & Olivera, 2016; DeArmond et al., 2016; Lejeune et al., 2016). It also has the highest noise levels than units that only provide lower neonatal care, which may be directly linked to the critical state of the neonates, as higher care facilities need more equipment and services for critically ill babies (Nathan et al., 2008; Valizadeh et al., 2013; Fortes-Garrido et al., 2014).
Public sector hospital's in the eThekwini District, that are regional, district and specialised level hospitals but do not have a fully functioning NICU.	District and specialised level, as well as some regional level hospitals may only provide lower care services, which do not consist of equipment and services seen in the NICU (White et al., 2013). Measuring noise levels in lower levels of care can produce confounding variables that can have an influence on the reliability of noise measurements. Therefore, NICUs without any intensive care services were excluded from the study.

3.5 Sampling Method

A purposive sampling method was utilized in the study as the researcher purposively selected public hospitals that have a fully functioning NICU. A purposive sample is one where people from a pre-specified group are purposely sought out and sampled (Gerrish & Lacey, 2010). Purposive sampling is used to justify the inclusion of rich sources of data that can be used to generate or test out the explanatory frameworks (Gerrish & Lacey, 2010).

3.6 Recruitment process

The current health system in South Africa is two-tiered with a public and private health care sector (Mahomed, Sturm & Moodley, 2017). The current study focused primarily on the public health sector, within which there are a variety of levels of care that are arranged according to a hierarchy of services. The National Health Act No. 61 of 2003 in Department of Health, 2012, presents a list of categories of public hospitals in each province, which includes district, regional, tertiary, central and specialised hospitals.

The act describes district hospitals, which are categorised into small, medium and large, depending on the number of beds they have (DoH, 2012, s 3). District hospitals serve a defined population within a health district and support primary health care. Regional hospitals provide health services in at least one of the following specialities: orthopaedic surgery, psychiatry, anaesthetics and diagnostic radiology (DoH, 2012, s 4). Regional hospitals receive referrals from several district hospitals and receive outreach and support from tertiary hospitals. Tertiary level hospitals provide specialist level services, as well as subspecialties of specialties and intensive care services under the supervision of a specialist (DoH, 2012, s 5). A central hospital must provide tertiary hospital services and central referral services, which are provided in high specialised units and at a small number of sites nationwide. Lastly, specialised hospitals provide specialised services such as psychiatric, tuberculosis, infectious diseases and rehabilitation services (DoH, 2012, s 7).

According to the list of public hospitals by DoH, two central hospitals and seven regional hospitals in the eThekwini District were listed at the time (DoH, 2012). Both central hospitals have an NICU, and four out of the seven-regional hospitals had a fully functioning NICU. The present study included two central hospitals, and three regional hospitals based on the inclusion and exclusion criteria. One regional hospital was excluded due to lack of feasibility (logistical reasoning, travelling cost, distance), which would have not influenced the outcomes of the study, as the sample of regional hospitals with NICUs in the eThekwini District were well represented.

The researcher sought information on the presence of the NICU in each hospital by telephonically contacting their neonatal department. The researcher attempted to contact the eThekwini Health Department to obtain the information on the presence of the NICU in each hospital but was told that such information was unavailable at the time. In South Africa, existing data bases are unable to determine the number of NICUs in the public and private sector, as well as the number and utilisation of neonatal intensive care and high care beds, number of patients admitted and discharged, and the number of human resources allocated to these units cannot be determined (Botha, 2014). Therefore, current data bases are insufficient for monitoring the status of neonatal intensive care services in South Africa (Botha, 2014).

3.7 Research sites

The researcher conducted a site survey to investigate the internal and external environment of each NICU. A description of each NICU was recorded on the site survey form (Appendix K) and the floor plans for each NICU can be seen in Appendices L2 to L5.

3.7.1 Hospital A.

Hospital A was a central level hospital, with the smallest NICU of 41.25 square meter (m^2), which was situated in a regular ward on the ground floor of the hospital and surrounded externally by a car park. The regular ward consisted of many units including a unit for term, preterm, and high care neonates, which were alongside each other and were separated by a low partition. The NICU was located next to the unit for preterm neonates, which required lower care then neonates in the NICU or high care units. In front of the NICU was the central nurse's station and the unit for high care neonates. At the time of measurement there were four neonates in the NICU, two of whom required intensive care and two who required high care services, as well as the NICU had one sink and one metal pedal bin (Appendix L2).

3.7.2 Hospital B.

Hospital B was a regional level hospital with a NICU size of 81.42m^2, which was situated on the roof floor. At the time of measurement there were 10 neonates in the NICU requiring intensive care services, including one neonate in the isolation cubicle. There were four sinks, one between each incubator, and one in the isolation cubicle, as well as nine metal pedal bins (Appendix L3). The NICU was enclosed, with no noisy processes occurring in the external environment, such as corridors and other units.

3.7.3 Hospital C.

Hospital C was a regional hospital, with an NICU size of 77 m^2 that was located next to other units such as the high care unit and the unit for preterm neonates, which were partitioned by high glass windows on either side. The central nurse’s station was in front of the entrance of the NICU, with a smaller nurse’s station inside. The NICU consisted of six incubators, five of which were occupied, and there was one wash area and 15 metal pedal bins, two of which were in front of each incubator and the other bins were located close to the entrance of the NICU (Appendices K and L4).

3.7.4 Hospital D.

Hospital D was a regional hospital, with an NICU size of 180m^2, however the NICU was located at the end of a bigger ward, which had a low care unit, isolation unit and high care unit. The SLM was centrally placed between the NICU and the high care unit as this section of the unit represented the NICU. The other units of the ward were partitioned by high walls and glass windows, with the ward being designed as an open plan area. The nurse’s station was located towards the left, closer to the NICU. At the time of measurement there were three neonates in high care and two neonates in intensive care, as well as the NICU had two wash areas and four metal pedal bins including one in the isolation cubicle (Appendices K and L5).

3.8 Data collection instruments and equipment

3.8.1 Data collection instruments.

3.8.1.1 A site survey form.

A site survey was conducted by the researcher in each hospital NICU at the start of the study (Appendix K). The content of the form was informed by relevant literature on site surveys for the analysis of noise in NICUs (Laroche & Fournier, 1999; Neille et al., 2014; Carvalhais et al., 2016). The site survey included measuring the NICU with a tape measure and recording the area and features of each NICU site to construct the floor plans (Appendices L2-L5). A plastic tape measure was used by the researcher to measure the area of the NICU in each hospital during the site survey.

3.8.1.2 Noise measurement form.

The noise measurements were recorded by the researcher on a noise measurement form, which included hourly time intervals for the morning, afternoon and night (Appendix N). The form included measurements recorded for LAeq, LAmin, LAmax and LZpeak for each measurement period.

3.8.1.3 Sources of noise checklist and field diary

The checklist was developed by the researcher and was based on previous literature measuring noise in the NICU (Laroche & Founier, 1999; Nathan et al., 2008; Neille et al., 2014) (Appendix O). The sources of noise listed in the checklist are categorised according to alarms of devices and human related sources of noise including various human vocalisations and objects noises, which was adapted from a study by Laroche and Fournier (1999). The researcher recorded the frequency of occurrence of the various sources of noise in each NICU in the field diary. The researcher also recorded hourly LAeq, LAmin, LAmax and LZpeak measurements and other specific changes in noise levels in the field diary (Appendices P1-P4).

3.8.2 Data collection equipment.

The noise levels were recorded using the SLM, which was the Cel 450 C Version 1.09 model and had a Cel 495 Class 2 microphone with all frequency bands operating in real time using a Class 0 filterer. The SLM was battery operated and included various functions such as, frequency weightings (A, C and Z), time weightings (slow, fast and impulse) and octave band analysis. The SLM consisted of a class 2 calibrator and was able to save the last four calibrations at 114.0dB at 1 kHz. The SLM stores before and after calibrations to ensure that the microphone remains calibrated throughout the measurement period. The SLM was placed on an adjustable three- legged tripod**,** which was used as a platform to support the SLM. The tripod was adjusted to hold the SLM one meter away from the ground during the measurement period, according to the standards (SANS, 2013).

3.9 Pilot study

A pilot study is a smaller version of the main study, which is conducted to investigate the feasibility of methods and processes that are key to the success of the main study (Thabane et al., 2010). The pilot study was conducted at an NICU in a central public hospital, in the eThekwini District that was not included in the main study and was conducted as a replica of the main study. The researcher wanted to assess the functioning of the SLM in the NICU, as well as the feasibility of the duration of the measurements and observation of the sources of noise. Based on the areas that required piloting, a sample of one hospital was sufficient to conduct the pilot study. Following completion of the pilot study, appropriate modifications were made to the data collection instruments and procedures (Table 3.2).

Table 3.2

Problems Identified, and Modifications Made Following Completion of the Pilot Study

Area	**Problems / Observations**	**Modifications**
Data collection Procedure		
Site survey	The researcher did not encounter any problems during the site survey.	No modifications were made.
Noise measurements		
Placement of SLM	The central site procedure was successful. The placement of the SLM had to be adjusted from the centre to avoid reflective surfaces and interference with staff activities.	Placement of the SLM was adjusted accordingly in each NICU.
Settings of SLM	The settings on the SLM remained the same.	No modifications were made
Duration of measurement	The duration of measuring the noise levels, that is for 48 hours was successful, but the SLM could not measure noise levels continuously for that long with one set of batteries. The level of activity in the NICU and high functioning of the SLM influenced the battery life of the SLM. Therefore, the measurement required to be stopped to change the batteries.	The batteries were changed three times after each time interval that is the: Morning (7h00-13h00) Afternoon (13h00-19h00) and Night (19h00-19h00) Joshi and Tada (2016) used the same time intervals to investigate noise levels in NICUs.
Observation of the sources of noise	The researcher was present in the NICU from 7h00 to 23h00 during the pilot study. Consistent with other studies, the majority of the sources of noise were during the morning, from 7h00 to 13h00 (Valizadeh et al., 2013; Ramm et al., 2017; Gallo & Olivera, 2016; Cohn, 2018). Observing the NICU during the morning, afternoon and night was not practical or feasible at the time.	Instead of observing the NICU during the morning, afternoon and night, the researcher observed the NICU only during the morning on a Sunday and Monday. As a result, *a sample* of the sources of noises were taken and activities that were observed were recorded in a field dairy for further analysis.

Data Collection Instruments		
Site Survey Form	The site survey form was implemented successfully.	No modifications were made.
Noise measurement form	The form to capture the measurements during each time interval was implemented successfully.	No modifications were made.
Sources of Noise Checklist	The checklist was used to identify the sources of noise and their frequency of occurrence in each NICU. The researcher found it practical to record observations in a field diary, as it provided intensive details of the sources of noise in the NICU and their frequency of occurrence.	The checklist and a field diary were used to observe sources of noise and their frequency of occurrence. The checklist was modified whenever a new source of noise was identified in each NICU. The frequency of occurrence was recorded in the field diary and then displayed on the sources of noise checklist.

3.10 Data collection procedure

3.10.1 Obtaining permission from relevant authorities.

Ethical clearance was obtained from the University of KwaZulu-Natal (UKZN) Humanities and Social Sciences Research Ethics Committee (HSSREC) (Appendix A). Thereafter, permission was obtained from the eThekwini District office, Department of Health (DoH) to access the selected public hospitals (Appendix B). Following permission from the District manager, the researcher obtained approval from the Provincial Health Research Ethics Committee (PHREC) (Appendix C) after uploading relevant documents on to the National Health Research Database (NHRD).

Following ethical approval from the relevant authorities, the researcher obtained permission to loan the research equipment from the UKZN Audiology department (Appendix D). Prior to commencement of the data collection process, an information document was provided to management at the selected hospitals for the study (Appendix E), to which they responded with letters of support (Appendices F-J). Thereafter, the pilot study was conducted from 05 January 2018 to 08 January 2018, and the main study was conducted from the 12 January 2018 to 5 February 2018. The data collection procedure will be described according to the steps that were taken to accomplish the objectives of the study.

3.10.2 Site survey.

According to SANS: 10083:2013, it is essential to conduct a site survey to obtain a plan or sketch of the measurement area before the actual assessment (SANS, 2013). The researcher conducted a walk- through inspection at each NICU site and used the site survey form to record relevant information of the internal and external environment (Appendix K). The researcher then used a tape measure to measure the area of each NICU, as well as contacted the building department in each hospital to obtain measurements of the NICU, which enabled the researcher to sketch the floor plans (Appendix L2-L5).

3.10.3 Noise measurements.

3.10.3.1 Calibration of SLM.

Prior to conducting noise measurements in the NICU, the SLM was calibrated by an accredited laboratory according to the South African National Accreditation System (SANAS). The UKZN Audiology department was provided with a certificate as proof of calibration (Appendices M1 and M2). The researcher had undergone specific training by the Technical supervisor at the UKZN Audiology department to ensure proper use and calibration of the SLM according to the manufacturing specifications of the SLM.

At the beginning of each data collection day, the researcher calibrated the SLM, to ensure that it remained calibrated throughout the measurement period. The microphone was calibrated according to the manufacturers specifications and was done in a room close to the neonatal ward that did not have any staff members at the time. The researcher attached the external calibrator to the SLM, which automatically tested the equipment and indicated a pass or fail result after 10 seconds. After ensuring that the SLM was calibrated, the researcher set up the SLM to measure the noise levels.

The SLM was set up in the following ways:

3.10.3.2 Location of the SLM.

A tripod was used to steady the SLM and the central site procedure was used to position it in each NICU setting (Nathan et al., 2008; Valizadeh et al., 2013; Fortes-Garrido et al., 2014; Van Reenen, 2016). The central site was determined by measuring the length and breadth of each NICU. The placement was not exact as the SLM had to be moved so that it was one-meter way from any reflecting surfaces to prevent reverberation according to the SANS (SANS, 2013). The floor plans provide a representation of where the SLM was placed in each NICU and is represented by a red circle on each floor plan (Appendix L2-L5).

3.10.3.3 Settings of the SLM.

In accordance with the SANS: 10083:2013 an A-weighted frequency weighting and a time-weighting of slow response was used and expressed in dBA, in LAeq, LAmin, LAmax, and LZpeak (SANS, 2013). A one-third octave band filter setting was used to determine intensities in low, mid and high frequencies (Gelfand, 2009).

The settings on the actual SLM were according to the manufacturers specifications and were as follows:

- (Cumulative measure) Measure mode: Third octave,
- (SLM Response) Weighting: A, Time weight: Slow phase, Peak weight: Z
- Frequency (Hz): Third Octave, 12Hz to 20 000Hz, Bands: 36,
- Configure: 115200 (It is recommended that the highest setting be selected to give the fastest communication) (Commonly used for direct communication with a portable computer),
- Graph Range: 0-120dB,
- Microphone: Free Field,
- AC Output (For calibration purposes): High (70-140dB)

3.10.3.4 Duration of measurement.

The noise measurements were conducted continuously for 48 hours on two consecutive days of the week. A Sunday and a Monday were purposively selected to represent a weekday and a weekend day, as research has identified significant differences in noise levels between weekdays and weekend days (Konkane & Oakley, 2012; Carvalhais et al., 2016). The measurements were taken in the morning (7h00-13h00), afternoon (13h00-19h00), and night (19h00-7h00) on each day and were recorded on the noise measurement form (Appendix N).

3.10.4 A sample of observations of sources of noise and their frequency of occurrence.

The researcher was continuously present in the NICU during the morning period (7h00-13h00) to observe possible sources of noise and concurrently measure the noise levels. The researcher was positioned near the SLM, to ensure that the SLM was functioning appropriately and to observe and record any changes in the LAeq, LAmin, LAmax and LZpeak, which could have been caused by a source of noise. The sources of noise and their frequency of occurrences were recorded on to the sources of noise checklist (Appendix O) and in field diaries (Appendices

P1-P4). During the observation period, the researcher concurrently recorded hourly LAeq, LAmin, LAmax and LZpeak measurements, as well as recorded specific changes in the noise levels in the field diary to identify noise levels before and after a specific noise event occurred (Appendices P1-P4).

The researcher left the NICU after the observation period and only returned to change the batteries and restart the SLM. The researcher manually restarted the SLM three times, which was after each completion of the morning, afternoon and night noise measurements (that is at 7h00, 13h00 and 19h00). Following the data collection procedure in the NICU, the researcher transferred the measurement and setup data from the SLM to a personal computer using the dB23 Windows based software, which was compatible to the Cel 450 C SLM that was used in the present study. It was necessary to transfer and remove the data from the SLM at the end of the data collection period at each hospital because of the lack of storage space on the SLM and to avoid losing data. The raw data from the dB23 software was then entered on Microsoft Office Excel worksheets and analysed by the researcher with the assistance of a statistician.

3.11 Data analysis

Following consultation with the statistician, the significance value for inferential statistics was set at $p < 0,05$. The statistical analysis was performed using a computer-based software namely, the Statistical Package for Social Sciences-25 (SPSS-V25). The data analysis used both descriptive and inferential statistics and will be described according to the objectives of the study.

3.11.1 To measure and determine any significant differences between the noise levels during the morning, afternoon and night and on a weekday and weekend in each NICU.

The measurements (LAeq, LAmin, LAmax and LZpeak) derived from the SLM using the dB23 software were tabulated on excel sheets and categorised according to the morning, afternoon and night on Sunday and Monday for each NICU. Descriptive statistics were used to identify the mean and standard deviations for each measurement, that were reflected on tables. Thereafter, inferential statistics, namely one-way Analysis of Variance (ANOVA), was used to compare the morning, afternoon and night to the mean LAeq measurements. The purpose of a one-way ANOVA is to compare the means of two or more groups on one dependent variable to identify a significant difference from each other (Urdan, 2011).

If a significant difference was found, the researcher used a post-hoc test to further investigate which group of frequencies were higher or lower. The post-hoc test allows you to compare each group mean to each other group mean and determine if they are significantly different (Urdan, 2011). There are several available post-hoc procedures, including the Bonferroni, Tukey, and Scheffe methods. In the present study, the Bonferroni post hoc t-test procedure was used to make comparisons between the noise levels as it is the most conservative of the procedures and is simple to use (Olejnik, Supattathum & Huberty, 1997). In the Bonferroni method, a two-sample, two-tailed t-test is done between each data set and a p-value for each of the comparisons are obtained (Olejnik et al., 1997).

3.11.2 To identify a sample of the sources of noise and their frequency of occurrence in each NICU.

The sample of the sources of noise were identified by the researcher through direct observations from 7h00-13h00 in each NICU on Sunday and Monday. The researcher recorded observations of the sources of noise and their frequency of occurrence in a field diary and on the checklist. After the data collection period the observations made in the field diary and their frequency of occurrences were displayed on excel worksheets and descriptive statistics was used to calculate frequency counts and percentages for each source of noise, which were represented in a table.

The sources of noise on the checklist was categorised according to alarms of devices, and human related noise (human vocalisations and objects noise). The researcher also observed changes in the LAeq, LAmax, LAmin and LZpeak during the observation time and observed sources of noise that could have contributed to the change in intensity, which was recorded in the field diary (Appendices P1-P4). The LAeq, LAmax and LZpeak measurements were displayed on bar graphs to illustrate comparisons and trends between the source of noise and their effect on the intensity.

3.11.3 To determine the frequency content of noise in each NICU

Octave band analysis results were transferred from the SLM using the dB23 software and displayed on excel worksheets for data analysis. Descriptive statistics were used to obtain the mean LAeq measurements from 20Hz to 20 000Hz, which were presented in tables and bar graphs to illustrate and identify trends of the frequency content during the morning, afternoon and night. The frequencies were further categorised in to low, mid and high ranges to identify significant differences between them using one-way ANOVA. The results were represented in tables and further analysed using the Bonferroni method to identify significant differences between each frequency range.

3.12 Reliability and Validity Considerations

Scientific research is governed by norms and values that serve as guidelines for all researchers, and that are tested by a criterion that must be built into the research design and methodology (Neuman, 2011). Reliability and validity are essential to fulfil these criteria (Trochim, Donelly & Arora, 2015).

3.12.1 Reliability

Reliability is defined as the consistency with which a measuring instrument yields a certain result when the entity being measured has not changed (Cohen, 2009). The present study conducted a pilot study to enhance the reliability of the data collection instruments and equipment in the main study, with the necessary modifications being made to the main study. Additionally, a site survey was conducted and floor plans of each NICU were developed to ensure the reliability of the results, should the study be conducted at a different time with the same instrument.

Reliability was maintained, as the researcher conducted the noise measurements and observed the sources of noise independently. The documentation of observations in the checklist and their frequency of occurrence were conducted by the researcher, who is independent of the research sites, hence results were unbiased and non-participatory, as she did not interact with the staff and activities being observed in the NICU (Gallo & Olivera, 2016). The researcher had undergone individual training sessions with the University of KwaZulu-Natal (UKZN) Audiology department’s technician to ensure proper usage of the SLM to ensure reliable measurements.

3.12.2 Validity

Validity of an instrument refers to the extent to which the instrument measures what it is supposed to measure (Cohen, 2009). *Internal Validity* is the extent to which the data it yields allow the researcher to draw accurate conclusions (Cohen, 2009). Internal validity requires examining, *content validity* (is when the full range of a concepts meaning is covered by the measure), and *construct validity* (is the approximate truth of the conclusion, that your method accurately measures what it claims to measure) (Trochim et al., 2015).

Content validity was maintained, as the checklist on the sources of noise was developed by consulting relevant international and local literature on noise in the NICU (Laroche & Fournier, 1999; Nathan et al., 2008; Neille et al., 2014). The construct that was measured were the noise levels and the gold standard to measuring noise being the SLM (Berger et al., 2003), which was utilised in the present study. The SLM was externally calibrated and accredited by the South African National Accreditation System (SANAS) (Appendices M1 and M2), as well as the researcher calibrated the SLM by following the manufacturers specifications at the start of each data collection day and ensured that it was calibrated throughout the measurement period to provide accurate results. The SLM was placed in a central location, which is the most appropriate method to use to represent the average noise level in the NICU (Nathan et al., 2008), which may also reduce measurement bias.

External Validity refers to the extent to which conclusions drawn can be generalized to other contexts (Cohen, 2009). The present study considered both regional and central hospitals in the eThekwini District and conducted noise measurements over a whole day and during different days, therefore the results can be generalised to other public hospital NICUs.

3.13 Ethical considerations

The following ethical considerations were adhered to:

3.13.1 Permission to conduct the study.

This study had been ethically reviewed and approved by the UKZN HSSREC (Appendix A), the DoH eThekwini District office (Appendix B) and the PHREC (Appendix C). The researcher provided the selected hospitals, Chief Executive Manager (CEO), Medical manager, and Head of the neonatal department with an information document (Appendix E) to which they responded with letters of support (Appendices F to I).

3.13.2 Informing NICU nurses.

Before starting the study, the hospitals NICU nurses were verbally informed about the study and informed that activities observed by the researcher will be strictly confidential. They were also informed that the SLM will only record noise levels, hence their voices and conversations will not be recorded.

3.13.3 Anonymity and confidentiality.

Anonymity and confidentiality were maintained as the hospitals management and staff were notified that the results of the study will be strictly confidential. The name of the hospital was not used, instead alphabetical codes were used, and the researcher did not require any patient or staff identification.

3.13.4 Infection control measures.

Beneficence and non-maleficence are defined as acting in the best interest of the patients and doing no harm to them (HPCSA, 2008). This was ensured by implementing infection control measures throughout the study to reduce the potential risk for cross-contamination and cross-infection (Kemp & Bankaitis, 2000). The researcher disinfected the research equipment by wiping it with an alcohol swab before entering the NICU. The use of an alcohol swab is reported to be an appropriate disinfectant in a hospital setting for equipment that has a low risk factor (WHO, 2004). The data collection equipment such as the SLM and tripod have a low risk factor, as they were positioned away from any NICU surfaces and were not in direct contact with the patient, nor did the researcher come into contact with any patient or treatment surfaces. The researcher followed the NICU infection control protocols established in each hospital and used appropriate clothing, namely scrubs to reduce the risk of infection.

3.13.5 Dissemination of results.

A summary of the results will be disseminated to the relevant medical managers following submission of the study, as well as a noise reminder poster will be attached to the summary and can be displayed in each NICU to promote a quieter NICU environment for the benefit of the neonate's recovery (Appendix Q). The final dissertation will be submitted to the KZN DoH, Health Research and Knowledge Management once the research has been completed.

3.13.6 Data management.

After completion of the study, the research data will be stored in a locked file cabinet in the Department of Audiology for a period of five years and will thereafter be disposed of by shredding.

3.14 Summary

The present study implemented an analytic observational study design and used a purposive sampling method. Public hospitals in the eThekwini District were purposively selected based on the selection criteria, resulting in a selection of four hospitals, one of which was central and three were regional hospitals, that were used in the main study. Following ethical approval and support from the relevant hospitals, the pilot study was conducted in one central hospital, which was not included in the main study.

A site survey was collected at the start of the data collection procedure to obtain a floor plan of each NICU. Following the site survey, noise measurements were taken in each NICU during the morning, afternoon and night on a Sunday and Monday in each NICU. Concurrently the sources of noise and their frequency of occurrence was observed, however observations were only conducted during the morning in each NICU. The data was analysed using descriptive and inferential statistics namely the one-way ANOVA and Bonferroni method. The researcher considered various reliability and validity aspects, as well as ensured that the study was conducted in an ethical manner.

Chapter 4. Results

4.1 Introduction

Data analysis is the process of separating data with the intention of finding meaningful answers to the objectives of the study (Polit and Beck, 2008). This chapter will provide the results of the study in accordance with the objectives of the study. The results were analysed using descriptive and inferential statistics.

4.2 To measure and determine any significant differences between the noise levels during the morning, afternoon and night and on a weekday and weekend in each NICU

Table 4.1 displays the mean LAeq, LAmax, LAmin and LZpeak during the morning, afternoon and night, during Sunday and Monday in all hospitals. The highest mean LAeq was 64,45dBA in hospital A during the afternoon. The highest mean LAmax was 94,10dBA in hospital D during the afternoon, and the highest LAmin was 54,65dBA in hospital B during the morning, whereas the highest LZpeak was 115,90dBA in hospital B during the afternoon.

Table 4.1

Mean LAeq, LAmax, LAmin and LZpeak levels during the Morning, Afternoon and Night

Hospital	**Shift**	**Mean (LAeq) (dBa)**	**Mean (LAmax) (dBA)**	**Mean (LAmin) (dBA)**	**Mean (LZpeak) (dBA)**
A	Morning	62,95	85,30	50,70	106,90
	Afternoon	64,45	86,85	51,05	107,25
	Night	61,45	87,20	49,85	110,30
B	Morning	63,60	90,35	54,65	110,80
	Afternoon	64,40	89,70	53,15	115,90
	Night	62,25	84,80	53,40	114,90
C	Morning	61,80	84,65	52,55	112,60
	Afternoon	62,90	82,10	52,05	105,55
	Night	61,20	84,95	51,50	106,95
D	Morning	61,10	87,90	44,40	110,40
	Afternoon	62,25	94,10	40,65	112,45
	Night	58,70	82,55	37,45	109,40

Table 4.2 presents one-way ANOVA results between mean LAeqs and different times of the day for each hospital. The highest mean LAeqs were seen during the afternoon in all hospitals and the lowest mean LAeqs were seen during the night in all hospitals. There were no differences found between the morning, afternoon and night in hospital A, p = 0,441, hospital B, p = 0,127, and hospital C, p = 0,846, when one-way ANOVA was conducted (Table 4.2).

However, a marginal difference was seen between the morning, afternoon and night in hospital D, p = 0,046 (W. Sibanda, personal communication, June 14, 2018) (Table 4.2). Further analysis using the Bonferroni method found that there were no significant differences between the mean LAeq and the morning and afternoon, p = 0,309, and afternoon and night, p = 0,069, but the mean LAeq between the morning and night were significantly different, p = 0,040 (Olejnik et al., 1997).

Table 4.2

One-way ANOVA Results of Mean LAeqs between the Morning, Afternoon and Night in each Hospital

Hospital	**Shift**	**Mean (LAeq) (dBA)**	**Std,dev, (dBA)**	**P value (α=0,05)**
A	Morning	62,95	2,33	0,441
	Afternoon	64,45	0,35	
	Night	61,45	2,62	
B	Morning	63,60	0,14	0,127
	Afternoon	64,40	0,14	
	Night	62,25	1,20	
C	Morning	61,80	3,11	0,846
	Afternoon	62,90	3,81	
	Night	61,20	0,98	
D	Morning	61,10	0,00	0,046
	Afternoon	62,25	1,20	
	Night	58,70	0,70	

Table 4.3

One-way ANOVA Results for Mean LAeqs on Sunday and Monday in each Hospital

Hospital	Day	Mean (LAeq) (dBA)	Std.dev. (dBA)	P value (α=0,05)
A	Sunday	61,86	2,59	0,234
	Monday	64,03	0,66	
B	Sunday	63,20	1,60	0,685
	Monday	63,63	0,61	
C	Sunday	60,10	0,45	0,028
	Monday	63,83	1,85	
D	Sunday	61,13	1,95	0,586
	Monday	60,23	1,76	

Table 4.3 presents one-way ANOVA results for mean LAeqs on Sunday and Monday in each hospital. Results obtained from one-way ANOVA indicated that there were no significant differences in hospital A, p = 0,234, hospital B, p = 0,685, and hospital D, p = 0,586, except in hospital C, a significant difference was seen between Sunday and Monday, p = 0,028.

4.3 To identify a sample of the sources of noise and their frequency of occurrence in each NICU

Table 4.4 provides a list of the sources of noise observed in each hospital and a percentage of the frequency of occurrence of each source of noise. It was found that the most frequently occurring sources of noise in each hospital were staff conversations (30,9%) in hospital A, alarms of devices (21,0%) in hospital B, closing of metal pedal bins (16,9%) in hospital C and staff conversations (24,0%) in hospital D. The most occurring object noise was the closing of metal pedal bins (20,0%) in hospital B. Sources of noise that were not observed in some hospitals, were coughing/sneezing, tearing tissue from dispenser, telephone/cell-phone ringing, washing utensils in metal sink, wheeling of trolley, foot traffic and music from radios or cell-phones.

Table 4.4

The Frequency of Occurrence for Sources of Noise Observed in each hospital

	Hospitals			
Sources of noise	**A (%)**	**B (%)**	**C (%)**	**D (%)**
Alarms of devices				
Monitors, Ventilators	18,5	21,0	9,2	17,3
Human-related noise				
Human vocalisations				
Staff conversations	30,9	10,5	9,2	24,0
Morning prayer/singing	1,2	2,0	0,7	1,0
Crying babies	8,6	5,7	0,7	1,9
Coughing/sneezing	2,5	0,0	2,1	0,0
Laughing of staff	9,9	1,0	2,8	5,8
Object noises				
Closing of metal pedal bin	3,7	20,0	16,9	4,8
Switching on tap	7,4	10,5	14,8	11,5
Tearing tissue from dispenser	0,0	11,4	11,3	11,5
Closing of cupboard door	1,2	4,8	9,2	0,0
Cleaning of bins	1,2	0,0	1,4	1,9
Moving chairs	4,9	2,9	5,6	1,9
Ringing telephone/cell-phone	1,2	0,0	2,1	5,8
Washing utensils in metal sink	1,2	0,0	0,7	0,0
Wheeling of trolley/equipment in NICU	0,0	1,0	2,1	1,9
Foot traffic	0,0	1,0	0,0	0,0
Dropping objects	1,2	1,9	0,7	1,9
Removing tape of boxes in the NICU	0,0	0,0	0,7	1,0
Shuffling/tearing items	2,5	2,9	4,9	0,0
Suctioning a baby	2,5	3,8	3,5	3,8
Nebulising a baby	0,0	0,0	0,7	0,0
Hand clapping by staff	1,2	0,0	0,7	1,0
Music from radio or cell-phone	0,0	1,0	0,0	2,9
Total	100%	100%	100%	100%

Note. Percentages have been rounded therefore discrepancies may occur between sums of component percentages and the total, as all percentages have been calculated using unrounded figures (United Nations Department of Economic and Social Affairs, 2014)

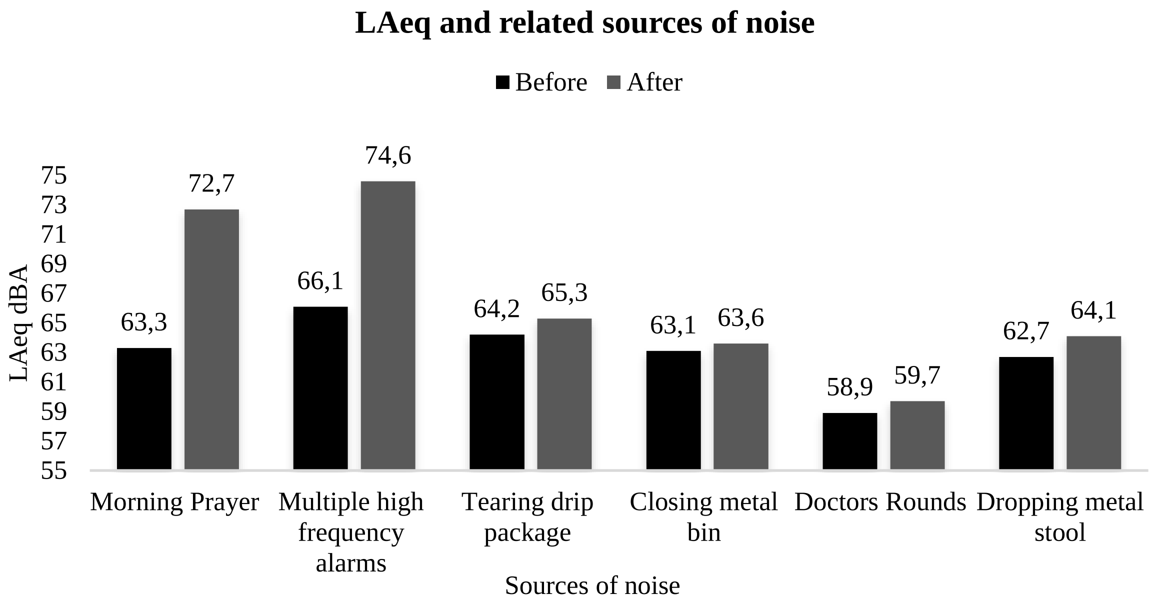

Figure 4.1. Description of the LAeq before and after the occurrence of various sources of noise.

In addition to the frequency of occurrence, Figure 4.1 provides a descriptive result of the LAeq measurements for various sources of noise, before and after the specific source of noise occurred. It was found that various activities increased the LAeq measurement such as the morning prayer (72,7dBA), the presence of multiple high frequency alarms (74,6dBA), tearing drip packages (65,3dBA), closing of metal bins (63,6dBA), doctor's rounds (59,7dBA) and dropping a metal stool (64,1dBA).

Figure 4.2 presents the LZpeak measurements for various sources of noise, before and after their occurrence. The sources of noise which increased the LZpeak were the presence of multiple high frequency alarms (109,7dBA), closing of a metal pedal bin (110,1dBA), doctor's rounds (103,6dBA), and dropping objects (116,0dBA, 110,8dBA).

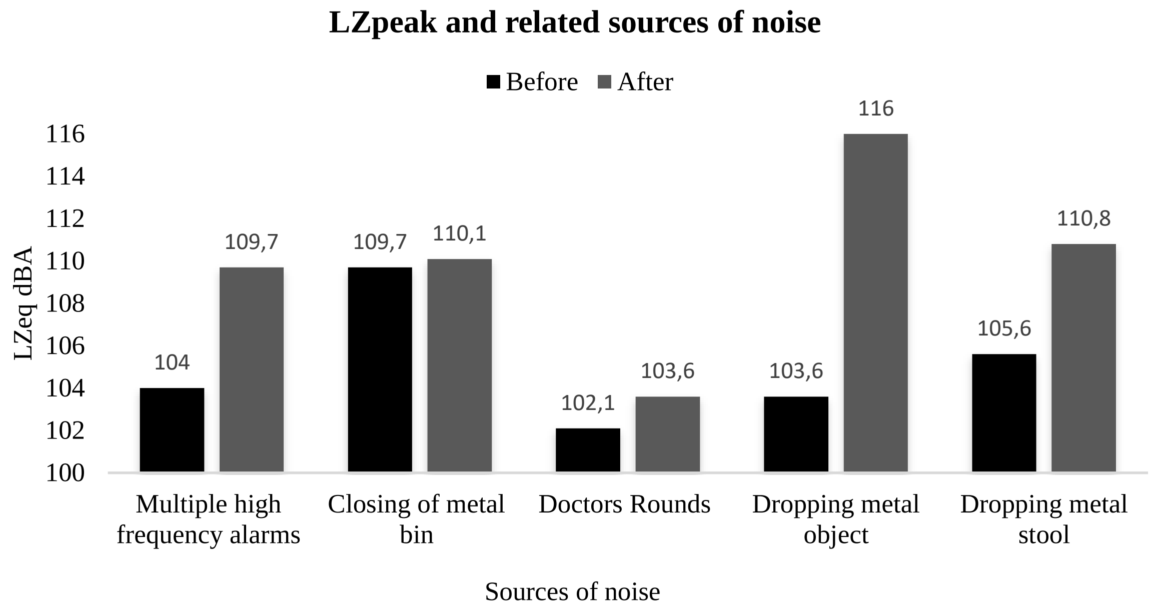

Figure 4.2. Description of the LZpeak before and after the occurrence of various sources of noise.

Similar sources of noise that influenced the LZpeak, were found to affect the LAmax as seen in Figure 4.3, the sources of noise that increased the LAmax were closing of a metal pedal bin (88,5dBA), dropping a metal object (84,5dBA) and dropping a metal stool (90,8dBA).

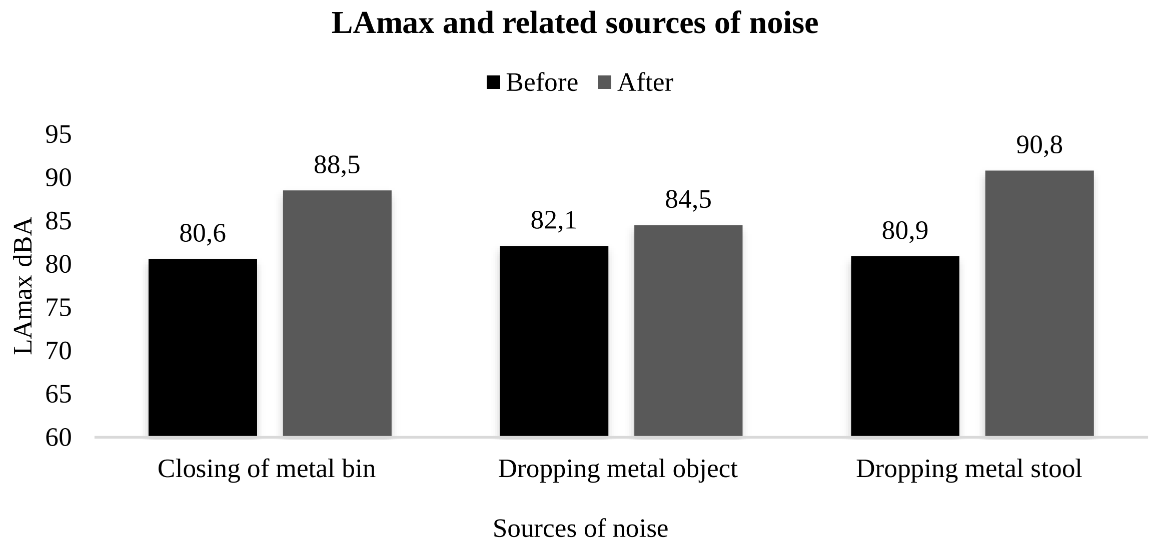

Figure 4.3. Description of the LAmax before and after the occurrence of various sources of noise.

4.4 To determine the frequency content of noise in each NICU

Figures 4.4 and 4.5 presents the frequency pattern of the mean LAeq levels from 20Hz to 20000Hz on a Sunday and Monday during the morning, afternoon and night. The frequency spectrums are nearly flat between 20Hz to 40Hz at the lower end of the low frequency spectrum. The mean LAeqs begin to gradually increase in the higher end of the low frequency spectrum from 50Hz to 200Hz. The curve then reaches its peak values in the mid to high frequencies from 200Hz to 8000Hz, and then gradually decreases at the higher end of the high frequency spectrum from 10000Hz to 20000Hz. LAeq levels greater than 45dBA were seen between 250Hz and 6300Hz during the morning, afternoon and night on Sunday and Monday (Figure 4.4 and 4.5).

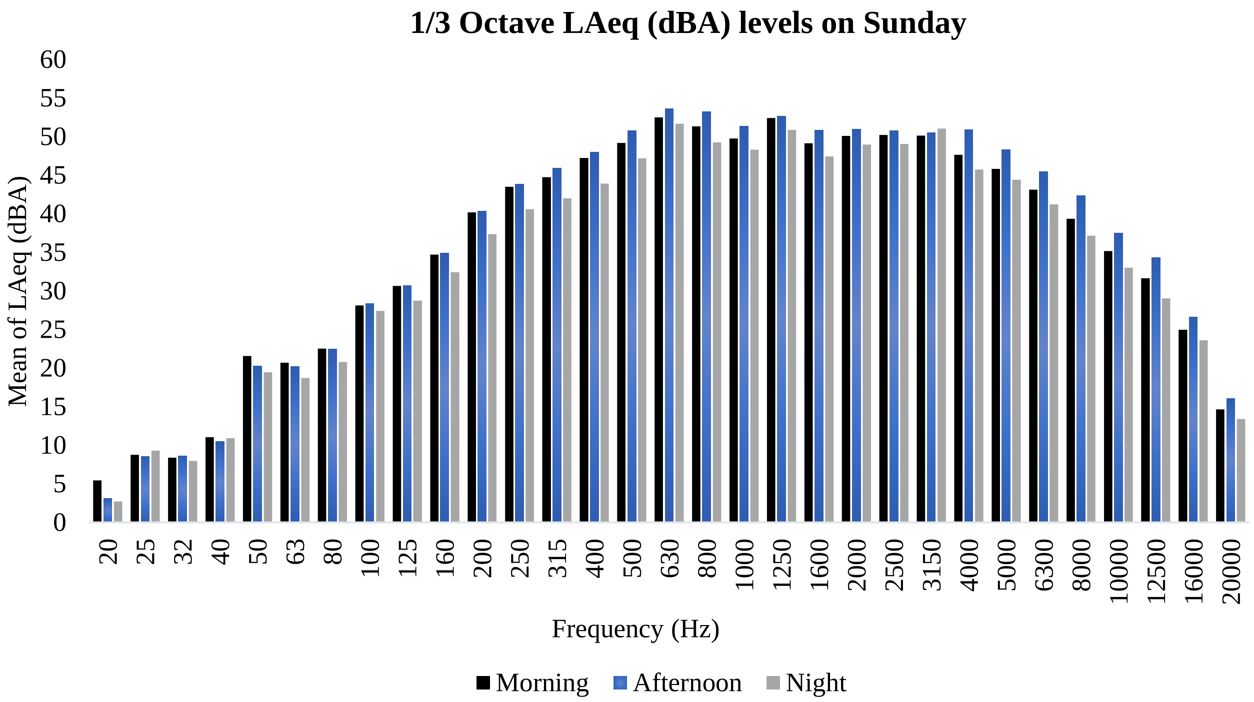

Figure 4.4. The frequency results of mean LAeqs on Sunday for all hospitals from the low frequencies (lower than 200Hz), mid frequencies (between 200Hz to 2000Hz) and high frequencies (higher than 2000Hz).

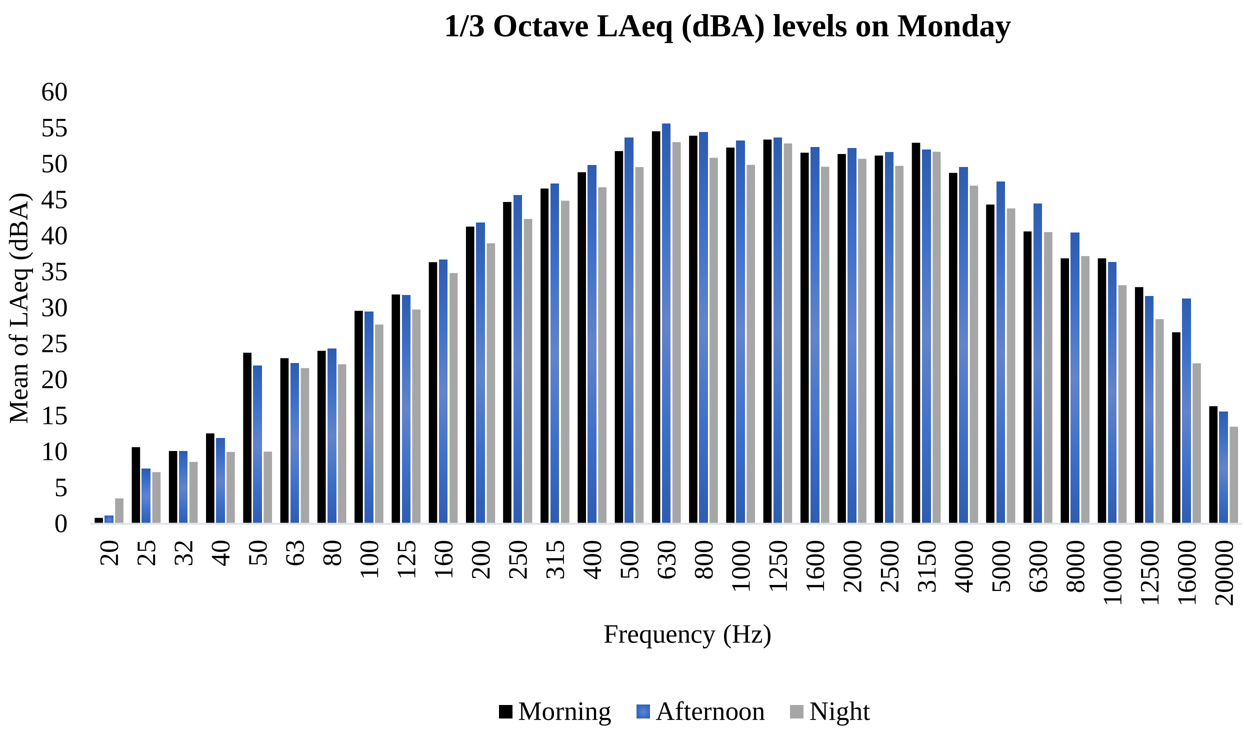

Figure 4.5. The frequency results of mean LAeqs on Monday for all hospitals from the low frequencies (lower than 200Hz), mid frequencies (between 200Hz to 2000Hz) and high frequencies (higher than 2000Hz).

Table 4.5 presents the mean LAeqs for the low, mid and high frequencies. The mid frequencies consist of the highest LAeq during the morning, afternoon and night shifts on Sunday and Monday. On Sunday, the afternoon had the highest LAeq level in the mid frequencies (*M*=50,03, *SD*=3,67), and the high frequencies (*M*=41,25, *SD*=11,79) as compared to the morning and night shift (Table 4.5). A similar result was seen on Monday, as the afternoon had higher LAeq levels in the mid frequencies (*M*=51,72, *SD*=3,77) as compared to the morning and night shift, except that the morning had a higher LAeq in the high frequencies (*M*=40,79, *SD*=11,30), as compared to the afternoon and night shift (Table 4.5).

Table 4.5

Mean LAeq Results for the Low, Mid and High Frequencies during the Morning, Afternoon and Night, on a Sunday and Monday

Day	**Shift**	**Frequency**	**Mean (LAeq)(dBA)**	**Std.dev.**
Sunday	Morning	Low	21,10	11,75
		Mid	48,88	3,41
		High	39,34	11,43
	Afternoon	Low	20,74	12,26
		Mid	50,03	3,67
		High	41,25	11,79
	Night	Low	19,62	11,38
		Mid	46,81	3,90
		High	37,88	11,75
Monday	Morning	Low	18,78	12,44
		Mid	50,85	3,72
		High	40,79	11,30
	Afternoon	Low	21,73	12,98
		Mid	51,72	3,77
		High	40,24	12,49
	Night	Low	19,97	11,53
		Mid	47,89	4,45
		High	37,58	11,83

Table 4.6 shows one-way ANOVA results for mean LAeqs between the low, mid and high frequencies on Sunday. The results indicate that there was a significant difference in the mean LAeq between the low, mid and high frequencies on Sunday, p = 0,006. Post hoc analysis using the Bonferroni method found that on Sunday, there was a significant difference between the low and mid frequencies, p = 0,012, and the low and high frequencies, p = 0,001, but there was no significant difference between mid and high frequencies, p = 0.972 (Olejnik et al., 1997).

Table 4.6

One-way ANOVA results for Mean LAeqs, between the Low, Mid and High frequency range on a Sunday

Day	**Frequency (Hz)**	**Mean (LAeq)(dBA)**	**Std.dev.**	**P value (α=0,05)**
Sunday	Low	20,49	11,73	0,006
	Mid	39,74	3,87	
	High	39,49	11,65	

Table 4.7 presents one-way ANOVA results for mean LAeqs between the low, mid and high frequencies on Monday. It was found that there is a significant difference between the low, mid and high frequencies on Monday, p = 0,009 (Table 4.7). Post hoc analysis using the Bonferroni method further identified a significant difference between the low and mid frequencies, p = 0,013, and the low and high frequencies, p = 0,002, but there was no significant difference between the mid and high frequencies, p = 0,825 (Olejnik et al., 1997).

Table 4.7

One-way ANOVA results for Mean LAeqs between the Low, Mid and High frequency range on a Monday

Day	**Frequency (Hz)**	**Mean (LAeq)(dBA)**	**Std.dev.**	**P value (α=0,05)**
Monday	Low	21,44	12,48	0,009
	Mid	41,31	4,02	
	High	39,68	12,00	

4.5 Summary

The highest mean LAeqs were observed during the afternoon in all NICUs, and the lowest mean LAeqs were observed during the night. The highest mean LAeq, LAmax, LAmin and LZpeak was 64,45dBA, 94,10dBA, 54,65dBA and 115,90dBA respectively. Results from one-way ANOVA showed a marginal difference, p = 0,046, in the mean LAeq between the morning, afternoon and night, as morning and night were significantly different, $p = 0{,}040$. There were no significant differences between LAeqs on Sunday and Monday, except in hospital C, $p = 0{,}028$.

Further investigation indicated that most frequently occurring sources of noise were staff conversations (30,9%), alarms of devices (21,0%) and closing of metal bin (20,0%). Multiple high frequency alarms, doctor's rounds, droppings of objects and closing of metal pedal bins were shown to have effect the LAeq and LZpeak and LAmax. Noise levels were the highest in the mid and high frequency range, with levels reaching above 45dBA between 250Hz and 6300Hz. One-way ANOVA found significant differences, between mean LAeqs in the low, mid and high frequencies on Sunday, $p = 0{,}006$ and Monday, $p = 0{,}009$.

Chapter 5. Discussion

5. 1 Introduction

The preceding chapter presented the results of the study, whereas the present chapter will establish continuity in the research by linking the results of the study to the research problem (Korrapati, 2016). The present study results will be compared to existing literature to identify similarities and differences. The results will be discussed in accordance with the objectives of the study, by discussing the noise measurements in relation to the time of day, the sources of noise and their frequency of occurrence and the frequency content of noise.

5.2 To measure and determine any significant differences between the noise levels during the morning, afternoon and night and on a weekday and weekend in each NICU

The present study found that mean noise levels during the morning afternoon and night in all hospitals well exceeded the AAP recommendations of 45dBA LAeq and 65dBA LAmax, which is consistent with previous studies (Laroche & Fournier, 1999; Nathan et al., 2008; Matook et al., 2010; Knutson, 2012; Valizadeh et al., 2013; Neille et al., 2014; Joshi & Tada, 2016; Carvalhais et al., 2016; Smith et al., 2018) (Table 4.1).

Joshi and Tada (2016) found significant differences (p < 0,05) between mean LAeqs during the morning, afternoon and night and the 45dBA recommendation. Additionally, Joshi and Tada (2016) found significant differences (p < 0,01) between mean LAeqs during the morning (77,89dB), afternoon (73,30dB) and evening (69,11dB) in the NICU. Noise levels were the highest during the morning in the majority of previous studies and may be due to the presence of staff rounds, treatment of patients, presence of staff conversations and alarms (Laroche & Fournier, 1999, Nathan et al., 2008; Matook et al., 2010; Valizadeh et al., 2013; Fortes-Garrido et al., 2014; Joshi & Tada, 2016; Carvalhais et al., 2016). Similarly, Matook et al. (2010) found significant differences ($p < 0,001$) between the noise level during the morning and night, due to the presence of fewer staff members and lower lighting that caused a decrease in conversations during the night.

The present study found a marginal difference ($p = 0,046$) between the mean LAeq during the morning, afternoon and night in hospital D, as further analysis indicated that there was a significant difference between the morning and night ($p = 0,040$) but not the morning and afternoon ($p = 0,309$) and afternoon and night ($p = 0,069$) (Table 4.2), which is consistent with a study conducted by Carvalhais et al. (2016). However, there were no significant differences found in the other three hospitals, like a study by Knutson (2012) who found that there were no significant differences between the morning and night as all night levels were within 3dB of the day levels. The findings suggest that in some NICUs and specifically the ones included in the present study, the activities in the NICU remained constant during the morning, afternoon and night.

The night period should provide a reduction in environmental stimuli that include less noise, lower lighting and less treatment activities, so that the neonate can have a period of uninterrupted sleep (Venkataraman et al., 2018). Additionally, the activity in the NICU should decrease from morning to night to assist the neonate in establishing a routine to differentiate the time of day. The understanding of the difference between time of day may assist the neonate in developing vital sleep cycles, for optimal growth and recovery, as well as uninterrupted sleep can aid in the formation of long-term synapses in the auditory cortex that facilitates learning (Venkataraman et al., 2018).

Given the present findings a change in noise levels may not be the reality in most NICUs, which may result in overstimulation, increasing the period for recovery due to lack of rest. The findings have implications for the development of practice guidelines in NICUs, which should stipulate that activities, such as ward rounds, x-rays and treatment procedures, when possible should not be conducted during the night. Due to the unstable and critical conditions of the neonate, this may be difficult to implement, yet certain environmental and behavioural modifications can be undertaken, such as dimming the light and closing the doors to external noise sources, as well as lowering of voices and staff conversations to create a calm acoustic environment, especially during the night (Konkani & Oakley, 2012; Ahamed et al., 2017; Venkataraman et al., 2018). Behavioural modifications and bringing about a change in noise culture, by posting signs as visual reminders can effectively improve the acoustic environment (McMahon et al., 2012; Ahamed et al., 2017) (Appendix Q).

Additionally, the consistent high noise levels throughout the day may alter the functioning of the auditory system, as the hair cells in the cochlea have no period for rest (Katz et al., 2009). Even in an occupational setting, the duration of exposure to noise is reduced should the noise level exceed the standard (85dBA) (Gelfand, 2009; Rawool, 2011; SANS, 2013). While, in the NICU, the noise levels are clearly exceeding the recommended standard of 45dBA, but the neonate is forced to stay in that environment for prolonged periods (Kanji & Khoza-Shangase, 2016). The preterm neonate's auditory system is at a critical period for auditory development, when in the NICU. Hence, exposure to continuous high noise levels throughout their prolonged stay in the NICU, may possibly alter the formation of important neural and auditory pathways responsible for processing, discriminating and memorizing auditory information (Rand & Lahav, 2014).

Previous studies indicate that due to the high noise levels, the neonate is unable to recognise meaningful speech, especially the maternal voice, which can affect the optimal wiring of structures in the brain responsible for language development (Picciolini et al., 2014; Rand & Lahav, 2014; Thakur et al., 2016; Venkataraman et al., 2018). Research indicate that the maternal voice not only provides a foundation for speech and language development but can also soothe the neonate which aids in recovery and growth (Rand & Lahav, 2014; Ramm et al., 2017; Sinha & Kumar, 2018; Filippa et al., 2017). Despite the benefits, maternal bonding is a major problem in the NICU, due to the neonate being too ill, inability to hold the neonate, as well the presence of high noise levels (Venkataraman et al., 2018).

The noise levels should be low enough and speech should be synchronous and directed to the neonate to overcome the barrier of a mixture of asynchronous noise in the background from alarms and conversations (Rand & Lahav, 2014). The findings have implications for education and training of NICU health care professionals and most importantly family members. Mothers should be encouraged to speak to their preterm neonates, as research indicates that the neonate prefers their mothers voice and native language over other female voices, which can also be taken as evidence that auditory memory and language development begins in the womb and should be optimized in the NICU (Rand & Lahav, 2014; Filippa et al., 2017). Further research is needed to determine whether exposure to linguistic stimuli in the neonatal period can improve long-term language and communication outcomes in neonates admitted to the NICU, possibly preventing learning disabilities that are commonly seen in the preterm population (Rand & Lahav, 2014).

Additionally, the present study found that mean noise levels in the NICU were higher during the afternoon, followed by the morning and night in all hospitals (Table 4.1). High noise levels during the afternoon can be related to the presence of visiting hours (Fortes-Garrido et al., 2014), shift changes, and more alarms been activated due to crying babies (Laroche & Fournier, 1999). The present study did not observe sources of noise during the afternoon, therefore reasons for the high noise levels cannot be made.

This study limitation should be addressed in future research by conducting observations during different times of the day. Additionally, the presence of the researcher may have influenced the noise levels, because the researcher was present during the morning and not the afternoon. The presence of the researcher and the awareness of staff to the noise been measured during the morning may have altered the behaviour of staff members resulting in lower mean LAeqs in the morning as compared to the afternoon. The findings may be related to the well-known Hawthorne effect, which has been observed in many other studies measuring noise in the NICU (Nathan et al., 2008; Livera et al., 2009; Valizadeh et al., 2013). This may have implications for future research that should consider hiding the SLM or alternating the researcher's presence to reduce the Hawthorne effect (Nathan et al., 2008; Matook et al., 2010).

The present findings also suggest that if noise is measured regularly in the NICU, it could create staff awareness, which may result in lower noise levels that were seen in the morning as compared to the afternoon. These findings have implications for intervention strategies such as implementation of noise measuring protocols. Hospitals should conduct and monitor noise measurements in the NICU as a standard practice to identify whether the noise levels are within the recommendations. It would be beneficial to monitor the noise levels daily, to identify whether they change on different days, as the present study found that there were no significant differences in noise levels between different days of the week, that is Sunday and Monday, except in hospital C were LAeq levels on Sunday were significantly different than Monday ($p = 0.028$) (Table 4.3).

A plausible reason for the significant difference between the days may be due to Sunday having less staff members and activities such as morning prayers and meetings as compared to Monday (Appendix P3). Similarly, previous research indicates that noise levels on Monday were higher than any other days of the week (Carvalhais et al., 2016; Gallo & Olivera, 2016), but Matook et al. (2010) found that Wednesdays had higher noise levels due to the presence of grand ward rounds. Future research should consider measuring noise levels throughout the week to identify weekly activities that may be contributing to the difference in noise levels (Matook et al., 2010).

The findings may have implications for policy makers to revisit existing international noise recommendations and guidelines, by considering the effect of duration and time of day on the noise levels, which may influence the neonate's auditory development. Future research should also investigate the differences between duration of stay in the NICU and the affect it may have on the neonate's auditory system. Additionally, the present findings provide contextually relevant information about noise during different times of the day and week, that may serve as a guide in developing South African guidelines that are specific to the NICU environment.

5.3 To identify a sample of the sources of noise and their frequency of occurrence in each NICU

The present findings also provide practical examples of various sources of noise that were identified in the NICUs and can be included in developing relevant guidelines to reduce their occurrence. The majority of the sources of noise were from alarms and human-related noise, which is consistent with previous studies (Nathan et al., 2008, Valizadeh et al., 2013; Forte-Garrido et al., 2014; Neille et al., 2014, Joshi & Tada, 2016; Carvalhais et al., 2016; Ahamed et al., 2017). Laroche and Founier (1999) found that conversations occurred 38% of the time, and Nathan et al. (2008) found that they occurred 36,0% of the time. Similarly, the present study found that the most frequently occurring source of noise was staff conversations (30,9%) in hospital A (Table 4.4).

Although, hospital A had the least number of nurses (four nurses) (Appendix K), it was a central hospital, catering for student training, multiple ward rounds and frequent visits from specialists, hence the presence of various health care professionals entering the NICU may have increased the number of conversations occurring. In support of this, the present study found that student and doctors ward rounds increased the LAeq to 59,7dBA, which was seen in hospital C, on Sunday (Figure 4.1) (Appendix P3, 11h00-12h00), and was also observed in previous studies (Matook et al., 2010; Valizadeh et al., 2013). The findings have implications for educating both medical staff and students about reducing loud conversations before entering the NICU, as well as limiting the number of people entering the ward at once which may reduce the occurrence of conversations (Valizadeh et al., 2013).

Additionally, hospital A had the smallest NICU (41.25m^2) (Appendix K), but the noise levels were as high as other NICUs. Despite been a central hospital, the NICU represented that of a normal ward, which is commonly seen in most hospitals in South Africa (Nathan et al., 2008). The NICU was separated from other units by low barriers that do not reach the ceiling, hence noise from other units, could be easily heard in the NICU. The inappropriate design of the NICU, may be a contributing factor to the overall noise level in the NICU. If the partitions were raised to the ceiling the noise levels may be significantly reduced (Evans & Philbin, 2000). Therefore, fewer activities, machines or occupants may not necessarily mean that the noise levels will be lower, if the design and room acoustics of the NICU is still lacking (Nathan et al., 2008). In South African hospitals, space and resources may be a major problem, therefore the design of an NICU may not be high on the list of priorities, but the findings suggest that more attention and urgency should be given in providing an appropriate setting for neonates due to their unique vulnerability to the adverse effects of noise in the NICU.

Additionally, the present study found that alarms were the second most frequently occurring source of noise (21,0%) specifically in hospital B (Table 4.4) and can be compared to previous findings by Gallo and Olivera (2016) who found that alarms occurred 25,16% of the time and Nathan et al. (2008) who found that alarms occurred 28,7% of the time. The high occurrence of alarms in hospital B, could be due to the higher number of neonates (10 babies) in the NICU and isolation cubicle, as compared to the other hospitals, however hospital A had four babies and the frequency of alarms were also high 18,5% (Table 4.4).

Therefore, the frequency of alarms may be related to the critical state of the neonates as critically ill neonates require more machines and monitoring which may have resulted in frequent alarms been activated (Valizadeh et al., 2013). The frequency of occurrence of alarms also depend on whether the nurses attend to alarms quickly and efficiently, as it may activate again if the problem is not solved, which was seen in the present study, as well as in a study by Valizadeh et al. (2013). The high occurrence of alarms is concerning as this study found that the presence of multiple high frequency alarms increased the LAeq to 74,6dBA and the LZpeak to 109,7dBA (Figure 4.1 and 4.2), which was seen on Sunday in Hospital B (Appendix P2, 8h00-9h00). Similarly, Ahamed et al. (2017) found that the intensity of mechanical ventilator alarms was between 70dBA and 75dBA.

The effects of alarms on the neonates are intensified considering the temporal pattern of the source of noise, as transient noise have found to cause physiological instability in the preterm neonate and inability to adjust to environmental stimuli (Almadhoob & Ohlsson, 2015; Venkatraman et al., 2018; Sinha & Kumar, 2018). Alarms can have a negative impact on sensory functioning, as neonates presented with inhibited manual tactile functioning when an alarm in the NICU was presented in comparison to a condition without the alarm (Lejuene et al., 2016). These findings have implications for behavioural modification of nurses and other health care professionals treating the neonate, as they should try to attend to alarms quicker, as well as reduce the volume of the alarm on the device (Nathan et al., 2008; Valizadeh et al., 2013).

In addition to alarms, the most frequently occurring object noise was the closing of metal pedal bins, specifically in hospital B (20,0%) and C (16,9%) (Table 4.4). It was observed that hospital B had nine metal pedal bins and hospital C had 15 metal pedal bins in the NICU (Appendices K, L3 and L4). Whereas, hospital A and hospital D had one and four metal pedal bins respectively, and their frequency of occurrence for closing metal pedal bins were lower than the other hospitals (Table 4.4). The frequent use of metal bins in the NICU may not be a problem, when it is closed quietly, but when the bin is closed abruptly the LZpeak was found to increase to 110,1dBA, which subsequently increased the LAeq 63,6dBA, and the LAmax to 88,5dBA (Figure 4.1, 4,2, 4,3) (Appendix P2, Sunday, 9h00-10h00).

Other object noises, which influenced the LAeq, LZpeak and LAmax measurements were dropping of metal objects on the ground (Figure 4.1, 4.2 and 4.3). Dropping of a metal stool was seen in hospital D on Sunday and increased the LAeq to 64,1dBA the LAmax to 90,8dBA and the LZpeak to 110,8dBA (Appendix P4, 8h00-9h00). The highest LZpeak of 116,0dBA was caused by dropping a metal object on the ground (Appendix P3, Sunday 12h00-13h00). Similarly seen in another study the greatest mean LZpeak (90-110dB) was caused by dropping metal objects on the ground (Valizadeh et al., 2013), which was found to occur 2,59 % of the time in the NICU (Gallo & Olivera, 2016). The relative effect that object noises have on all noise metrics indicate that they may be major contributors to the overall noise level and require immediate intervention.

Intervention may address many areas to reduce the source of noise, including environmental modifications such as reduction of metal pedal bins in the room, use of alternative bins and stools, such as plastic ones, use of protector pads on bin lids, and most importantly, educating and changing the behaviour of nurses when closing bins and handling other object sources of noise. Moreover, considering the high occurrence and intensity levels of closing metal pedal bins, staff should consider positioning metal bins further away from the neonate, as this study observed that the bins were directly next to the neonate's head (Appendices L3 and L4). Theoretically, the closer a noise source is to the receiver the higher the intensity will be that reaches the receiver; doubling the distance of the source of noise from the receiver can reduce the noise by 4 to 5dBs (Berger et al., 2003). As dBA is a logarithmic unit, a 3dBA difference reduces the intensity of the noise by half, therefore a 4dBA difference should substantially decrease the intensity of the noise levels (Valizadeh et al., 2013).

The present study also found that a possible contributor to the overall noise level was the presence of the morning prayer which was conducted at 7h00-8h00. The morning prayer has not been mentioned in other studies investigating noise in the NICU, and reasons for this may be that the morning prayer may not be an international practice or that the researchers did not find it to be a source of noise. In South Africa, studies investigating noise in the NICU did not observe the sources of noise at 7h00-8h00 in the morning, therefore the presence of the morning prayer may have been overlooked (Nathan et al., 2008; Neille et al.,2014).

It is a common practice to hear praise songs echoing through the corridors of South African hospitals as they are thought to be off spiritual importance to give hope and comfort to patients (Monareng, 2013). Research suggest that singing is the most common and simplest form of spiritual nursing care in South African public hospitals specifically found in KZN (Chandramohan & Bhagwan, 2016). Future research, especially in studies outside of KZN, should investigate the presence of the morning prayer in other NICU hospitals and its influence on the overall noise levels, which was observed in the present study.

This study found that in hospital A, the morning prayer was conducted directly outside the NICU whilst the door remained open. The prayer lasted for 30 minutes and was conducted by all staff members. A similar practice was seen in hospital C, on Monday, when the morning prayer was conducted by more than 20 nurses directly outside the NICU and increased the LAeq from 63.3dBA to 72.7dBA and lasted for 30 minutes (Appendix P3). It was observed that longer prayers had a direct influence on the intensity of the LAeq measurement.

The LAeq measurement is based on analytical results, which considers the objective part of the definition of noise that indicate that a source is considered as noise if it is harmful to the receiver. Alternatively, noise is also defined as been subjective, and related to its desirability, hence the morning prayer may not be regarded as a source of noise to the nurses. These findings suggest that in addition to conducting analytical studies of noise levels in the NICU, it is also important to obtain information on the perceptions of nurses on sources that they may perceive as been noisy, as the morning prayer is a spiritual practice and is intended to provide healing to the patient and may not be considered as a noise hazard in the NICU.

It is suggested that nurses should be key role players and decision makers in the development of noise protocols in the NICU, which may prevent infringement on their work performance and their attitude towards noise monitoring. Nevertheless, objective findings are crucial and should be brought to the attention of staff members, because it shows that certain sources of noise may not be perceived as harmful but may be high enough to disrupt the neonate's auditory system, as well as can cause physiological instability.

Therefore, the findings do not suggest that the morning prayer be eliminated, but possible suggestions in reducing its effect on the noise levels should be discussed with nurses. Practical suggestions may include closing the NICU door when the prayer is being conducted outside the NICU or conducting the prayer for a shorter duration. Research indicated that doors and windows can serve as an acoustical barrier or partitions between the source of noise and the receiver. A closed door, without sound seals can reduce noise by 20 to 24dB (Evans & Philbin, 2000).

The modification of closing the NICU door can also be applied to eliminate external sources of noise from the corridor such as foot traffic, wheeling of trolleys and conversations. However, the researcher observed that a few nurses closed the NICU door, when they noticed an increasing amount of noise outside the NICU, despite their efforts, other nurses did not follow the same etiquette, and as a result the NICU door remained open. The difference in noise control behaviours between nurses indicate that they may benefit from education and training, as well as the implementation of a noise control protocol may ensure that all staff adhered to the same practices.

5.4 To determine the frequency content of noise in each NICU

Morning prayers, staff conversations, noise from alarms and object noise consist of frequencies that are in the mid to high frequency range (Livera et al., 2008; Kokani & Oakley, 2012; Rand & Lahav, 2014). The observation of these sources of noise correlate with one-third octave band results found in this study, which indicate that the highest LAeqs were in the mid and high frequencies during the morning afternoon and night and on Sunday and Monday (Table 4.5). Further analysis found that LAeqs greater than 45dBA were seen between 250Hz-6300Hz, which corresponds mostly to frequencies in the mid and high frequency range (Figure 4.4 and 4.5).

Similarly, Livera et al. (2008) observed that noise sources in the NICU predominantly consist of mid to high frequencies from 500Hz-8000Hz because of vacuum cleaners, dropping objects, switching tap on, pushing trolleys, ringing phones, moving chairs, staff rounds, conversations and crying babies. Lejuene et al. (2016) found that a high frequency alarm in the NICU has a frequency of 2450Hz. Moreover, Lahav and Skoe (2014), found that neonates were exposed to nearly 20% more sound within the speech frequency range (501- 3150Hz) compared with the night time (p = 0,018).

The present study observed that noise found from 250Hz-6300Hz, which approximately constitutes most of the mid frequencies and the lower end of the higher frequencies, was higher than 45dBA during the morning, afternoon and night, with the highest LAeq measurements seen during the afternoon. The higher LAeq measurements found during the afternoon in the mid and high frequencies support LAeq measurements found in objective one of the study and suggest that noise activity increased during the afternoon. The findings have implications for education and training, as nurses should be aware about the effects of the sources of noise, and which activities may contribute to the harmful effects of mid and high frequency noise in the NICU.

The effects of mid to high frequency noise is concerning as preterm neonates are physiologically unable to protect themselves from high frequency noise, which is primarily due to the development of the cochlea (Livera et al., 2008). Due to preterm birth, the neonate’s cochlea is still developing, making it difficult to adapt to high frequency sounds, without the protection of maternal tissue (McMahon et al., 2012). Additionally, the portion of the cochlea consisting of high frequencies is the most vulnerable to outer hair cell damage due to the tonotopically organised cochlea (Lahav & Skoe, 2014). Therefore, preterm neonates in the NICU are susceptible to developing a high frequency hearing loss due to over exposure of noise for long periods of time in the NICU. In addition, preterm neonates are also exposed to other risk factors that can result in a high frequency sensory neural hearing loss.

Among the risk factors are, the use of ototoxic medications but are not limited to aminoglycosides, which are often treated as the first line antibiotics in neonates and are widely accepted in the NICU, however they are known to damage both the cochlea and vestibular organs due to cell damage (Wroblewska-Seniuk et al., 2017). The damage to hair cells from aminoglycosides affects high frequency hearing and progresses to involve lower frequencies (Zimmerman & Lahav, 2013). Moreover, neonates are commonly exposed to other risk factors for hearing loss such as prematurity, very low birth weight, low Apgar score, intensive care treatment with mechanical ventilation, hypoxia, hyperbilirubinemia, exposure to HIV and prolonged stay in the NICU (greater than 48 hours) (Kanji & Khoza-Shangase, 2012; Zimmerman & Lahav, 2013). Hence, long-term, careful monitoring and the appropriate audiological management of hearing loss is essential among preterm neonates (Wroblewska-Seniuk et al., 2017)

Infant hearing screening is an effective procedure in the early detection of hearing impairment in infants and should therefore be prioritized in neonatal care, however some institutions perform screening based on risk factors only, which was proven to identify only 50-75% of neonates with hearing loss (Wroblewska-Senuik et al., 2017). While, it is now recommended to conduct Universal New-born Hearing Screening (UNHS) in all infants (Wroblewska-Seniuk et al., 2017), in developing countries, such as South Africa, it is not yet feasible nor fully implemented (Olusanya, Luxon & Wirz, 2004; Nathan et al., 2008; Kanji & Khoza- Shangase, 2012).

Possible barriers to UNHS include a high burden of diseases and many risk factors, manpower shortages and cost relating to clinical and management aspects (Nathan et al., 2008; Kanji & Khoza Shangase, 2012). Many neonates are lost after initial hearing screening to follow-up, as South Africa lacks a national data base to effectively track neonates and infants enrolled in National Hearing Screening programs (Botha, 2014; Kanji & Khoza-Shangase, 2016). Therefore, Kanji and Khoza-Shangase (2016) suggest that risk-based hearing screening should be conducted as a starting point, followed by a risk-based surveillance program to track infants.

Kanji and Khoza-Shangase (2016) also found that it may be difficult to conduct hearing screening in the NICU, due to the high noise levels, resulting in unreliable results, high referral rates and false positive results, which can influence the hearing screening outcomes and cause unnecessary concern for parents who receive negative feedback about their babies hearing status (Kanji & Khoza-Shangase, 2016). The findings have implications for the constant monitoring of noise levels in the NICU for better hearing and health outcomes. Audiologist that are commonly affiliated with hearing screening in the NICU, should take a more proactive role in ensuring that noise levels are low enough for hearing screening to be successfully implemented. The present study findings may also have implications for modification of existing Early Hearing Detection and Intervention (EHDI) programs in South Africa, to prioritise noise measurements in all NICUs, which may increase the effectiveness of such programs.

In the light of implementing programs, the study observed that none of the hospitals had any noise control programs in place and did not implement any noise control strategies. Therefore, findings from the present study may be used to inform the research sites, as well as other local hospitals about the high noise levels and the sources of noise that were observed, which may have implications for developing intervention programs. However, the outcomes of environmental modifications and staff behavioural modifications have been questioned in previous studies due to the lack of change in high noise levels, but research indicate that this may be due to gaps in intervention programs in the NICU (Carvalhais et al., 2016; Ramm et al., 2017; Smith et al., 2018). Nathan et al. (2008) found that after four months of attempting to provide feedback and arrange a group session with the nurses in the NICU, the nurses could not find the time to attend them.

It may be likely that the nurses lacked motivation to attend the sessions- despite their possible lack of motivation, all the nurses in the NICU suggested that increasing awareness of noise levels and its adverse effects through staff training will reduce staff generated noise (Nathan et al., 2008). Therefore, the study findings suggest that the nurses are interested in education and training, but their motivation may depend on their interest towards the approach of intervention. Previous research indicate that the traditional instructional training methods fail to engage workers and may instil negative attitudes towards work place safety (Albert & Hallowel, 2013). Literature indicates that adults learn differently to children and that andragogy was a better term for providing knowledge to adults than pedagogy. Pedagogy is a teacher directed authoritative method of learning, where the learner is dependent and needs to adjust to the requirements set by the instructor (Albert & Hallowel, 2013). In andragogy the learning methods are adopted based on the learner's interests and needs, motivation to learn and solve problems and active involvement in the learning process (Bryan, Kreuter, & Brownson, 2009; Taylor & Hamdy, 2013).

The nurse's role should not only be to receive information but to also challenge and construct knowledge and change their own perception, views and beliefs (Albert & Hallowel, 2013). The andragogy-based safety training framework is built on the assumption that learners are self-directed and responsible for learning (Albert & Hallowel, 2013). Future research should consider confirming the andragogy framework when developing and implementing an intervention program that aims to reduce noise levels in the NICU.

The first step in developing an intervention program should be to create a committee, which may be driven by nurses, who can be responsible for noise control in the NICU (Mazer, 2009). The Audiologist may also play a key role in providing information on the effects of noise on the neonate and noise control strategies based on theoretical evidence, as well as implement noise measurements using the SLM. This information may be introduced into the education and training programs and may be carried over to other shifts of nurses and health care professionals. The present study found that the sound environment is diverse, including not only noise at the neonate's bedside, but also noise that reach the bedside from the source and the path to the neonate, more so the noise is not only caused by nurses, but by students, and other medical professionals. Thus, establishing a multidisciplinary noise control committee, may spread the accountability for the noise from the various sources that were identified in the present study (Mazer, 2009).

The committee may also be responsible for monitoring noise levels and identifying possible sources of noise in the NICU. It is evident, from the present study findings that each NICU operates differently with nurses that may have differing behaviours and attitudes towards noise, therefore noise control strategies must be contextually relevant to each NICU. It is important that NICU staff members model sound sensitive behaviour and demonstrate their important role of been an advocate for the patient (Mazer, 2009). Perhaps changing the mindset of NICU health professionals towards noise can be the solution to the exceedingly high noise levels, which may improve the health outcomes of vulnerable neonates in the NICU and later in life.

5.5 Summary

The present findings are exceedingly higher than the recommendations, which can result in negative outcomes for the health and recovery of preterm neonates. The LAeq levels were higher than the recommended standard during the morning, afternoon and night, which indicate that the neonate is being exposed to harmful noise for their entire stay in the NICU. The results suggest that there is a great need for noise control intervention and behavioural modification in the NICU. The presence of alarms, staff conversations, dropping of objects occurred the most in the NICU, and can also be controlled with behavioural modification and greater education and training.

Moreover, the frequency content of the noise in the NICU predominantly consisted of mid-high frequency noise, increasing the risk of hearing loss and other developmental problems. Sources of noise producing mid and high frequency noise require urgent intervention to reduce their adverse effects on the neonate. The present study found essential contributory factors to the high noise levels that can be targeted to reduce noise in NICUs in public hospitals, which suggest that appropriate implementation of noise control strategies and a change in noise culture in these hospitals is still needed.

Chapter 6. Conclusion

6.1 Introduction

High noise levels in the NICU is a long-standing public health concern, with little having been done to mitigate the presence and negative effects on vulnerable neonates. Research has found that high noise levels can cause physiological instability and developmental complications seen later in life (McMahon et al., 2012; Thakur et al., 2016; DeArmond et al., 2016; Joshi & Tada, 2016; Cohn, 2018, Venkataraman et al., 2018). Due to the adverse effects of high noise levels and the vulnerability of preterm neonates, standards have been recommended, however researchers argue that they have various gaps and more research is required to inform existing standards (Knutson, 2012; Rand & Lahav, 2014). Therefore, the present study aimed to investigate the noise levels in NICUs in public sector hospitals in the eThekwini District and to identify the contributing factors to the high noise levels.

6.2. Summary of findings

Consistent with other studies, the present studies results indicated that noise levels in NICUs are exceedingly higher than the recommended 45dBA standard (Laroche & Fournier, 1999; Nathan et al., 2008; Knutson, 2012; Valizadeh et al., 2013; Neille et al., 2014; Joshi & Tada, 2016; Carvalhais et al., 2017; Smith et al., 2018). The study identified that the time of day and the noise levels was a contributory factor, as the highest noise levels were found during the afternoon in all hospitals. The researcher's absence during the afternoon may have increased the occurrence of conversations which resulted in higher noise levels. Moreover, the researcher observed sources of noise in the morning period and not the afternoon period hence cannot account for the actual sources of noise during the afternoon. Future research should consider ways to observe all the sources of noise in the NICU, at different times of the day whilst reducing the Hawthorne effect seen in studies where, Matook et al. (2010), hid the SLM in a wooden box, and Jahangir Blourchian and Sharafi (2015) audio recorded the noise events.

Although noise levels were higher in the afternoon, there were no significant differences between the mean LAeq in morning, afternoon and night, in all hospitals except hospital D, where a marginal difference was found (p = 0,046). This study also found that there were no significant differences between the mean LAeq on a Sunday and Monday, except in hospital C (p = 0,028). Therefore, the present study findings suggest that in the majority of the hospitals, similar activities occur throughout the day and night resulting in consistent high noise level for 24 hours. The findings suggest that there is an urgent need for change in the NICU, as continuous high noise levels for prolonged periods may increase the risk for developing a hearing loss and health complications on the vulnerable neonates.

This study also found that a variety of sources contribute to the high noise levels in the NICU, with the major sources of noise been that of alarms and human-related noise, which may be controlled with environmental modifications and behavioural changes. The source-path-receiver model indicate that the most effective method of reducing noise is by targeting the source of the noise, and by identifying that the majority of the sources of noise are alarms and human-related noise, this can be reduced or eliminated with effective intervention strategies.

The framework of the study provided beneficial information, as sources of noise and their path to the neonate were discovered. The study found that morning prayers outside the NICU increased the LAeq, therefore strategies should be implemented to reduce the noise at the source and along path, such as decreasing the duration of the prayer, or ensuring that the NICU door is closed. Other sources of noise that were identified were closing of bins and loud staff conversations, which are near and often have an unhindered path to the neonate, therefore environmental modifications such as replacing metal bins for plastic bins or moving it away from the neonate, as well as behavioural modifications such as closing the bins slowly to reduce the intensity of the noise may be beneficial to the overall noise level. By using the source-path-receiver model, various sources of noise and control strategies could be identified in a systematic way, therefore future research, as well as staff members should consider this approach when assessing noise in the NICU.

Additionally, the present study further analysed the spectrum of noise in the NICU, by conducting octave band analysis, and the results suggest that the noise in the NICU is mostly dominated by mid and high frequencies, which was consistent with other studies (Livera et al., 2008; Knutson, 2012; Konkani & Oakley, 2012). The mid frequencies were the highest during the afternoon which indicate that human vocalisations occurred the most during the afternoon. The presence of mid and high frequency noise in the NICU, can increase the likelihood of neonates acquiring a high frequency sensory neural hearing loss in combination with other co-occurring conditions. The potential risk of high frequency noise in the NICU is further increased by the fact that the frequency content of NICU noise is rarely monitored as the majority of studies in the field focus on measuring intensity levels (Lahav & Skoe, 2014).

High noise levels have been found to have both an immediate effect that causes distress to the infant and lasting effects on their overall development. Prior concern over the amount of sound produced around neonates has been an issue in the NICU, but with the advances of medical technology, the NICU has become an even noisier environment. Multiple studies have demonstrated that there is a need to identify noise reducing interventions to aid in neonatal growth factors, but very few studies have been conducted to identify evidence-based practice interventions.

As nurses play a central role in monitoring and maintaining the stability of neonates, it is important that they have evidence-based practice guidelines that they can implement to safeguard the neonate from environmental stressors such as noise (Manske, 2017). The present study had identified practices relevant to South African NICUs, which indicated that practices found to cause the most noise are human-related. Hence, rather than budget being the primary barrier to improvement, the noise culture in current NICUs unknowingly weakens the importance of noise control in the NICU (Mazer, 2012). Nurses and other health care professionals affiliated with the NICU need to become more proactive in monitoring their contribution to the auditory environment by designating specific noise control protocols (Mazer 2012). Implementing a cultural shift through targeted education, behavioural modifications and some environmental changes can be a positive step in revisiting an intra uterine experience in the NICU (Ahamed et al., 2017).

6.3 Significance of the study

The study provided beneficial information by comparing the time of the day and noise levels, as well the frequency content of noise, which can assist in bridging gaps that have been found in existing literature and recommended standards. As the results indicate that preterm neonates are at an increased risk of developing a high frequency hearing loss, policy makers should consider developing and implementing protocols and guidelines on noise levels that are specific to the South African context. Noise levels should be measured routinely in all NICUs to ensure that guidelines are been adhered too. Guidelines on Early Hearing Detection and

Intervention (EHDI) should include accurate research and guidelines on measuring noise levels in the NICU, as it can influence appropriate and timely hearing screening and intervention.

The findings of the study are significant as they have implications for health promotion and awareness in the NICU. The mere implementation of the study, and presence of the SLM provided awareness about noise levels among staff members in the NICU, therefore the findings may provide beneficial information that can promote changes in the workplace to monitor and regulate the noise levels. A change may not be immediate but can be a starting point for promoting safer noise levels, and as a result a safer auditory environment for neonates to recover in.

6.4 Critique and limitations

The study conducted noise measurements on a Sunday and Monday, based on findings from previous literature that identified differences between noise levels on a week day and weekend. The lack of significant differences between Sunday and Monday may suggest that sources of noise could have occurred on other days and may have been overlooked by the study, as well as other days may have been louder. Moreover, the frequency of occurrence of sources of noise observed by the researcher were subjective and may not be a true reflection of the NICU environment. The researcher counted the frequency of sources of noise that were perceived as loud, but that may not be the case for another person. Hence, to count the occurrence of sources, a research assistant should be present to ensure that the results are not biased. Additionally, the sources of noise can be recorded electronically to reduce observer bias.

6.5 Practical Implications

The findings can assist NICU management staff in conjunction with nursing staff to develop protocols and guidelines to reduce behaviours that cause a high LZpeak and LAeq. The issue of noise should be addressed daily such as in the morning meeting, as a key priority. The major sources that increased the noise levels and occurred frequently were staff conversations dropping of objects, closing of metal pedal bins and alarms, which may serve as practical examples that can inform nurses about possible noise activities and the effect it has on the noise levels and the neonate. Additionally, the findings on the sources of noise and their effect on the noise level can serve as motivation for hospital management to provide alternative cost-effective objects that are less noisy, for example metal pedal bins can be replaced with plastic bins.

Specific noise sources were also identified with the use of frequency analysis seen in the present study. Collecting frequency specific information provided more insight into the amount of auditory damage the neonates are been exposed to while in the NICU. The findings can assist in the of implementation engineering controls such as shielding noisy equipment, changing ventilation systems, or installing sound-absorbing materials in celling or floor tiles. Different materials can absorb and reflect sound at different frequencies, so knowing where the most noise is occurring would allow to us to choose the most appropriate noise control strategies (Cohn, 2018).

6.6 Research Implications

International studies stipulate that educational programs, behavioural modifications and environmental alterations often do not appear to be effective in bringing the ICU noise levels to within recommended limits (Konkani & Oakley, 2012). In the South African context, there is limited research that have implemented intervention strategies and have measured noise levels post intervention. By using the present studies results, future research should focus on the intervention aspects for noise control to expand on existing findings.

Future research should also investigate existing protocols and standards in hospitals, with regards to noise control strategies. There is limited research on environmental noise control in hospitals, and the problem may be the lack of appropriate standards. Currently, there are a few research studies that looked at the perspectives of nurses regarding noise in the NICU, yet their education and awareness about noise standards in the NICU may be lacking. Therefore, future research should also investigate the knowledge of health care professionals regarding noise standards. The information may assist researchers in understanding gaps in education and training about noise levels, that require immediate enforcement.

The present study used the source-path-receiver model as a framework for the study, however focused on identifying characteristics of the source. Future research should investigate the characteristics and the effect of intervention strategies along the path of noise before it reaches the neonate. The majority of the research have provided many suggestions to reduce noise at the path such as use of absorbent materials (curtains, carpets, blankets) and use of barriers, but limited research is available that practically assesses the effect of these strategies on the noise levels in an NICU environment.

6.7 Conclusion

The valuable work of health care professionals, and the constant struggle of vulnerable and critically ill neonates to stay alive may be hidden by the adverse effects of noise in the NICU. The high quality of care seen in these specialised units should also be reflected in the acoustic environment. Noise in the NICU should no longer be ignored and assumed to be an inevitable part of institutional care, unavoidable alarms or unintended activities and should not be part of the hospital experience for a distressed family and a critically ill neonate (Mazer, 2009). The current findings concur that many sources of noise are preventable or can be mitigated with minor environmental modifications, and that in the short-term, health professional education and training may result in a behavioural change, which in the longer term, may facilitate a cultural shift towards a quieter NICU (Ramm et al., 2017). The findings of this study may be a stepping stone towards promoting a change in the way that noise in the NICU is viewed and managed, which may result in better short-term health outcomes for vulnerable neonates and possibly improve developmental outcomes later in life.

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Appendix A. Letter of approval from the UKZN Humanities and Social Sciences Research Ethics Committee (HSSREC)

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

12 December 2017

Ms Sabah Ismail 212502151
School of Health Sciences
Westville Campus

Dear Ms Ismail

Protocol reference number: HSS/1903/017M
Project title: An analytical study invetigating noise levels in Neonatal Intensive Care Units (NICUs) within the public sector in the eThekwini district

Full Approval – Expedited Application

In response to your application received 12 October 2017, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Dr Shenuka Singh (Chair)
Humanities & Social Sciences Research Ethics Committee

/pm

cc Supervisor: Ms Seema Panday
cc Academic Leader Research: Professor Johan Van Heerden
cc. School Administrator: Ms P Nene

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
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Website: www.ukzn.ac.za

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Appendix B. Letter of approval from the eThekwini District office, Department of Health (DoH)

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

DIRECTORATE: CORPORATE SERVICES

83 King Cetshwayo Highway
Mayville, Durban, 4001
Tel: 031 240 5455 Email: avashri.harrichandparsad@kznhealth.gov.za
www.kznhealth.gov.za

ETHEKWINI HEALTH DISTRICT OFFICE

13 November 2017

Dear Ms. S Ismail

Re: Permission To Conduct Research at eThekwini District Facilities.

This letter serves to confirm that your application to conduct the research study titled: “An analytical study investigating noise levels in Neonatal Intensive Care Units (NICUs) within the public sector in the EThekwini district” in the eThekwini district at the following health care facilities has been recommended:

1. Mahatma Gandhi Memorial Hospital
2. R K Khan Hospital
3. Addington Hospital
4. Prince Mshiyeni Memorial Hospital
5. King Dinuzulu Hospital Complex
6. King Edward VIII Hospital
7. Inkosi Albert Luthuli Central Hospital

Please also note the following:

1. This research project should only commence after full ethical approval, has been granted,
2. That you adhere to all the policies, procedures, protocols and guidelines of the Department of Health with regards to this research.
3. All research activities must be conducted in a manner that does not interrupt clinical care at the health care facility,
4. Ensure that this office is informed before you commence your research
5. The District Office/Facility will not provide any resources for this research
6. All logistical details must be arranged with the CEO/medical manager /operational manager of the facility,
7. You will be expected to provide feedback on your findings to the District Office/Facility

Yours sincerely

Dr. A. Harrichandparsad
pp Ms. T. P. Msimango
Chief Director (Acting)
eThekwini Health District

Fighting Disease, Fighting Poverty, Giving Hope

Appendix C. Letter of approval from the Provincial Health Research Ethics Committee (PHREC)

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

Physical Address: 330 Langalibalele Street, Pietermaritzburg
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Tel: 033 395 2805/ 3189/ 3123 Fax: 033 394 3782
Email:
www.kznhealth.gov.za

DIRECTORATE:
Health Research & Knowledge Management

HRKM Ref: 480/17
NHRD Ref: KZ_201711_031
Date: 7 December 2017

Dear Ms S. Ismail
UKZN

Approval of research

1. The research proposal titled **'An analytical study investigating noise levels in neonatal intensive care units within the public sector in the eThekwini District'** was reviewed by the KwaZulu-Natal Department of Health.

   The proposal is hereby **approved** for research to be undertaken at Addington, Inkosi Albert Luthuli Central Hospital, King Edward VIII, King Dinuzulu, Prince Mshiyeni Memorial, RK Khan and Mahatma Gandhi Memorial Hospital.

2. You are requested to take note of the following:
   a. Make the necessary arrangement with the identified facility before commencing with your research project.
   b. Provide an interim progress report and final report (electronic and hard copies) when your research is complete.

3. Your final report must be posted to **HEALTH RESEARCH AND KNOWLEDGE MANAGEMENT, 10-102, PRIVATE BAG X9051, PIETERMARITZBURG, 3200** and e-mail an electronic copy to hrkm@kznhealth.gov.za

For any additional information please contact Mr X. Xaba on 033-395 2805.

Yours Sincerely

Dr E Lutge
Chairperson, Health Research Committee
Date: 07/12/17

Fighting Disease, Fighting Poverty, Giving Hope

Appendix D. Loan declaration letter for use of SLM

UNIVERSITY OF KWAZULU-NATAL ™
INYUVESI YAKWAZULU-NATALI

UNIVERSITY OF KWAZULU-NATAL
PRIVATE BAG X54001
DURBAN 4000
2017 -12- 15
HS : ASSET SECTION

COLLEGE OF HEALTH SCIENCES
COLLEGE FINANCE OFFICE (ASSETS)

ASSET LOAN DECLARATION FORM

NAME OF STAFF :	BLESSING JILI
STAFF NO.:	7530
DEPARTMENT:	AUDIOLOGY
NAME OF COMPANY	MS. SABAH ISMAIL

Kindly allow the bearer to take the following item/s: (FOR SECURITY/RISK MANAGEMENT RELEASE)

ASSET NO	DESCRIPTION
0405417	CEL-450 SOUND LEVEL METER

SIGNATURE : [signature]

PRINT NAME : V Govender

DATE : 15 Dec 2017

Notes:

The School Manager/Head of School must authorize all equipment that is loaned and must ensure that the equipment is returned at the end of the agreed loan period.

Any loan equipment that is lost or damaged whilst on loan must be replaced by the person responsible for the custodianship and use of the equipment on loan.

Assets donated, on loan or on hire - department must advise all details of purchased/ hired/ on loan assets so that the moveable assets register can be updated timeously.

Contact Details:
Postal Address: Private Bag X54001, Durban, 4000
Telephone: 031 260-2263 Facsimile: 031 260-7727
Email : mbilik@ukzn.ac.za Website: www.ukzn.ac.za

Physical Address : College Finance Office
Desmond Clarence Building - Ground Floor

Appendix E. Information document to hospital management

DISCIPLINE OF AUDIOLOGY
SCHOOL OF AUDIOLOGY, OCCUPATIONAL THERAPY & SPEECH-LANGUAGE PATHOLOGY
FACULTY OF HEALTH SCIENCES
Tel: 031 260 7438
Fax: 031 260 7622
Email: naidoor1@ukzn.ac.za

UNIVERSITY OF
KWAZULU-NATAL

December 2017

To whom it may concern

Re: Information document to conduct research study

My name is Sabah Ismail, I am an Audiology student from the University of KwaZulu-Natal (UKZN). To obtain my Master in Audiology I am conducting a study titled 'An analytical study investigating noise levels in NICUs within the public sector in the eThekwini District'.

The study aims to investigate noise levels in all public hospitals that consist of a NICU. A Purposive selection criterion was used to maintain a similar NICU environment across all hospitals. Hospitals that were selected are listed as follows:

1. Mahatma Gandhi Memorial Hospital
2. R K Khan Hospital
3. Addington Hospital
4. Prince Mshiyeni Memorial Hospital
5. King Dinuzulu Hospital Complex
6. King Edward VIII Hospital
7. Inkosi Albert Luthuli Central Hospital

The researcher will conduct a walk-through site survey in the hospitals NICU to identify various structural and operational components of the unit to develop a floor plan. This will take place over a short duration during the day. The researcher will then conduct actual noise readings and observations to identify noise sources. This will take place over two days, which will be a Sunday and a Monday for a period of 24 hours of each day. A data collection plan will be provided to each hospital, so that they are aware of the day and time of the study.

The researcher will arrive on the morning of the data collection days and will place a small instrument known as a Sound Level Meter (SLM) in the middle of the NICU. A SLM is a safe instrument used to measure noise. The SLM will be placed in a central location in each NICU which will not interfere with any staff and patient activities. The SLM will remain in the same place for the period of two days. The researcher will conduct observations in the NICU at every hour. The researcher has undergone training and necessary practice to utilize the SLM.

The study will not cause any risk and discomfort to the babies. The SLM does not produce any noise and is not harmful to the babies' health. The researcher will ensure proper infection control methods always to avoid cross contamination and harm to patients. The SLM will only record the noise in the room and will not record voice and conversations.

The researcher will not require to contact the patients or obtain any patient and staff identification. The researcher's observations will be performed in a confidential and unbiased manner. The staff member and hospitals identity will remain confidential, as no staff and hospital names will be used in the study, instead alphabetical codes will be used. At the end of the data collection process, a summary of the results will be provided to each hospital. After completion of the study, the research data will be stored in a locked file cabinet in the Department of Audiology for a period of 5 years and will thereafter be disposed of by shredding, should the study not be published. All electronic data will be deleted following the completion of the study.

Noise is a well-documented environmental stressor in the NICU setting and shown to have adverse effects on the baby's health. Research indicate that the effects of increased levels of noise and overstimulation in the NICU may result in sleep deprivation, physiological instabilities (change in heart rate, blood pressure, respiratory rate, and oxygenation) and hearing loss especially in combination with ototoxic medication.

There are many sources of noise in the NICU, some of which include alarms resulting from machines, loud conversations, falling objects, telephones ringing, baby's crying etcetera. Some of these noise sources cannot be avoided, however practical strategies can be implemented to reduce the overall noise in the unit. Unfortunately, both international and local literature indicate that noise levels in the NICU well exceed the recommended standards, hence placing vulnerable babies at a further risk. Hence the study aims to investigate noise levels in the NICU and identify sources of noise. More direction and research can guide audiologist in establishing and implementing noise assessments and monitoring programs as well to engage in awareness and prevention campaigns with NICU staff. By analysing sound levels in NICUs in public hospitals, proper protocols can be designed to detect the cause responsible for generation of structural and operational noise, hence to reduce the noise levels in NICUs.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee and the Provincial Health Research and Ethics Committee.

In the event of any problems, concerns or questions you may contact the researcher,

Ms. S. Ismail on Tel: 083 512 5503, Email: ismail.sabah12@gmail.com and/or the supervisor Ms. S. Panday on Tel: 031 260 7623, Email: Pandayse@ukzn.ac.za

You are also welcomed to contact the UKZN Humanities and Social Sciences Research Ethics Committee as follows:

Humanities & Social Sciences Research Ethics Administration
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
Kwazulu-Natal, South Africa
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: Hssrec@Ukzn.Ac.Za

Yours sincerely,

Ms. S. Ismail — Researcher

Ms. S. Panday — Research Supervisor

Appendix F. Letter of Support from Inkosi Albert Luthuli Central Hospital (IALCH)

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

DIRECTORATE:

Physical Address: 800 Bellair Road, Mayville, 4058
Postal Address: Private Bag X08, Mayville, 4058
Tel: 0312401059 Fax: 0312401050 Email: ursulanun@ialch.co.za
www.kznhealth.gov.za

Office of The Medical Manager
IALCH

Reference: HSS/1903/017M
Enquiries: Medical Management

7 December 2017

Ms S Ismail
School of Health Sciences
Westville Campus

Dear Ms Ismail

RE: PERMISSION TO CONDUCT RESEARCH AT IALCH

I have pleasure in informing you that permission has been granted to you by the Medical Manager to conduct research on: **An analytical study investigating noise levels Intensive Neonatal Care Units (NICUs) within the public sector in the eThekwini district.**

Kindly take note of the following information before you continue:

1. Please ensure that you adhere to all the policies, procedures, protocols and guidelines of the Department of Health with regards to this research.
2. This research will only commence once this office has received confirmation from the Provincial Health Research Committee in the KZN Department of Health.
3. Kindly ensure that this office is informed before you commence your research.
4. The hospital will not provide any resources for this research.
5. You will be expected to provide feedback once your research is complete to the Medical Manager.

Yours faithfully

....

Dr L P Mtshali
Medical Manager

Fighting Disease, Fighting Poverty, Giving Hope

Appendix G. Letter of Support from R.K. Khan Hospital

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

DIRECTORATE:

Physical Address : R.K. Khan Circle
Physical Address : CHATSWORTH
Tel: [031] 4596001 Fax:[031] 4011247 Email:Sharon.gounden@kznhealth.gov.za
www.kznhealth.gov.za

R.K. KHAN HOSPITAL
OFFICE OF THE CEO

ENQUIRIES : DR P.S. SUBBAN

18 December 2017

Ms Sabah Ismail [Student No. 212502151]
School of Health Sciences
Westville Campus
University of Kwazulu-Natal

Dear Madam

RE: PERMISSION TO CONDUCT RESEARCH: AN ANALYTICAL STUDY INVESTIGATING NOISE LEVELS IN NEONATAL INTENSIVE CARE UNITS [NICUs] WITHIN THE PUBLIC SECTOR IN THE ETHEKWINI DISTRICT

Permission is granted to conduct the study at this institution.

Please note the following:

1. Please ensure that you adhere to all the policies, procedures protocols and guidelines of the Institution with regards to this research.

2. Please ensure this office is informed before you commence your research and your University's Ethics approval must be attached.

3. You will be expected to provide feedback on your findings to this institution.

4. You will be liaising with : Mrs A.M. Fayers
   Chief Speech Therapist
   Tel : [031 – 4596524]

Yours faithfully

DR P.S. SUBBAN
CHIEF EXECUTIVE OFFICER

... KHAN
HOSPITAL / HOSPITAAL
18 -12- 2017
PRIVATE BAG / PRIVAATSAK
X004
CHATSWORTH 4030

Appendix H. Letter of Support from King Edward VIII Hospital

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

OFFICE OF THE HOSPITAL CEO
KING EDWARD VIII HOSPITAL

Private Bag X02, CONGELLA, 4013
Corner of Rick Turner (Francois Road) & Sydney Road
Tel: 031-3603853, Fax:031-2061457; Email: rejoice.khuzwayo@kznhealth.gov.za
www.kznhealth.gov.za

Ref.: KE 2/7/1/(02/2018
Enq.: Mrs. R. Sibiya
Research Programming

10 January 2018

Ms. S. Ismail
School of Health Sciences
Westville Campus
UNIVERSITY OF KWAZULU-NATAL

Dear Ms. Ismail

Protocol: "An analytical study investigating noise levels in Neonatal Intensive Care Units (NICU's) within the Public Sector in the eThekwini District."
REF. NO. HSS/1903/017M

Your request to conduct research at King Edward VIII Hospital has been approved.

Please ensure the following:

- That King Edward VIII Hospital receives full acknowledgment in the study on all publications and reports and also kindly present a copy of the publication or report on completion.

Before commencement:

* Discuss your research project with our relevant Clinical Head/Assistant Nursing Manager
* Sign an indemnity form at Room8, CEO's Complex, Admin. Block.

The Management of King Edward VIII Hospital reserves the right to terminate the permission for the study should circumstances so dictate.

Yours faithfully

SUPPORTED/~~NOT SUPPORTED~~

DR. SA MOODLEY
ACTING SENIOR MEDICAL MANAGER

12/01/2018
DATE

Appendix I. Letter of Support from Prince Mshiyeni Memorial Hospital

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

DIRECTORATE: Senior Medical Manager

Mangosuthu Highway, Private Bag X 07
MOBENI
Tel: 031 907 8317/8304 Fax: 031 906 1044 Email:myint.aung@kznhealth.gov.za
www.kznhealth.gov.za

Prince Mshiyeni Memorial Hospital

Enquiry: Dr M AUNG
Ref No: 50/RESH/2017
Date: 30/01/2018

TO: Ms Sabah Ismail

RE: LETTER OF APPROVAL TO CONDUCT RESEARCH AT PMMH

Dear Researcher;

I have pleasure to inform you that PMMH has granted to conduct research on **"An analytical study investigating noise levels in neonatal intensive care units within the public sector in the eThekwini district"** in our institution.

Please note the following:

1. Please ensure this office is informed before you commence your research.
2. The institution will not provide any resources for this research.
3. You will be expected to provide feedback on you finding to the institution.

With kind regard

MYINT AUNG
Senior Medical Manager & specialist in Family Medicine
MBBS, DO(SA), PGDip in HIV (Natal), M.Med.Fam.Med (natal), PhD
Tel: 031 9078317
Fax: 031 906 1044
myint.aung@kznhealth.gov.za

Fighting Disease, Fighting Poverty, Giving Hope

Appendix J. Letter of Support from Addington Hospital

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

ADDINGTON HOSPITAL

P.O. BOX 977
DURBAN
4000
Tel: 031-327-2970 Email: reshma.boodhai@kznhealth.gov.za
www.kznhealth.gov.za

OFFICE OF THE CHIEF EXECUTIVE OFFICER

Reference: *9/2/3/R*

Date: 31st January 2018

Principal Investigator:
- **Ms S Ismail**

PERMISSION TO CONDUCT RESEARCH AT ADDINGTON HOSPITAL: "AN ANALYTICAL STUDY INVESTIGATING NOISE LEVELS IN NEONATAL INTENSIVE CARE UNITS (NICU) WITHIN THE PUBLIC SECTOR IN THE ETHEKWINI DISTRICT"

I have pleasure in informing you that permission has been granted to you by Addington Hospital Management to conduct the above research.

Please note the following:

1. Please ensure that you adhere to all the policies, procedures, protocols and guidelines of the Department of Health with regards to this research.
2. This research will only commence once this office has received confirmation from the Provincial Health Research Committee in the KZN Department of Health.
3. Please ensure this office is informed before you commence your research.
4. Addington Hospital will not provide any resources for this research.
5. You will be expected to provide feedback on your findings to Addington Hospital.

DR M NDLANGISA
HOSPITAL MANAGER
ADDINGTON HOSPITAL

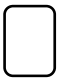
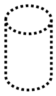
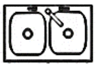
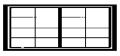
Fighting Disease, Fighting Poverty, Giving Hope

Appendix K. Site Survey form

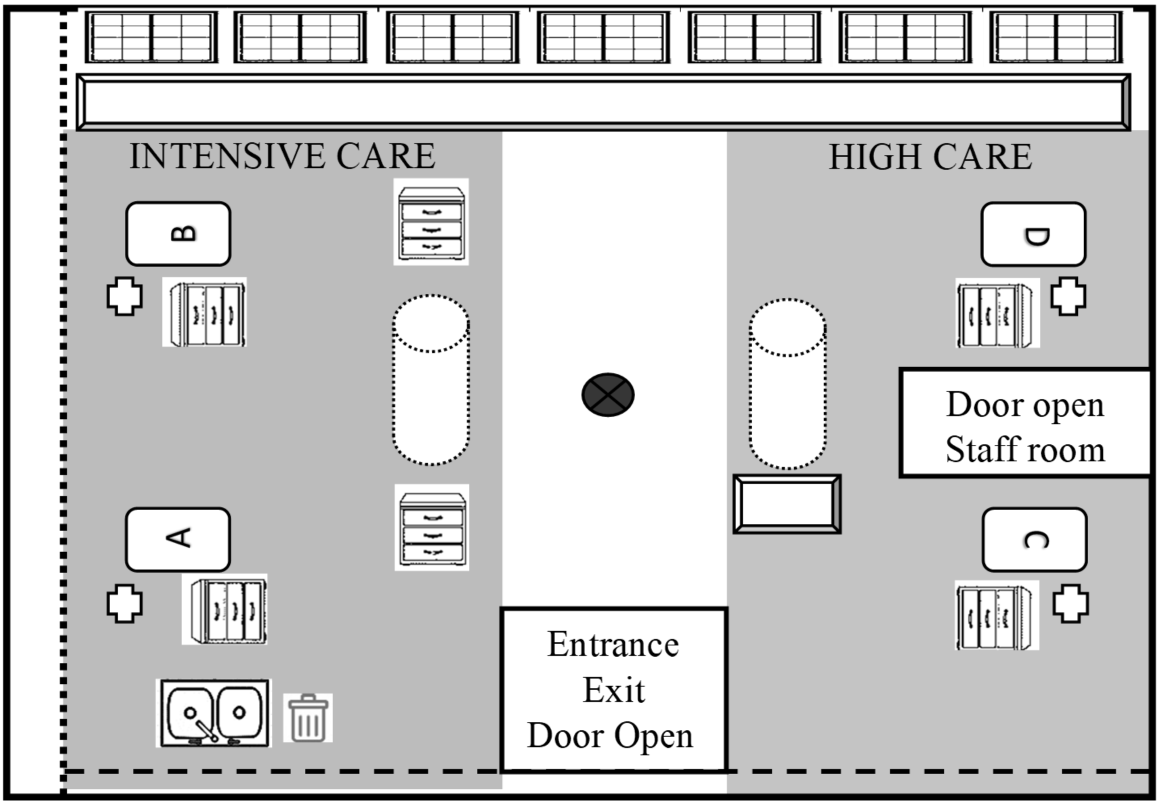
Area	A	B	C	D
External Environment (Corridors) (Other Noisy processes)	Corridor Nurses station directly outside NICU Other neonatal units attached (open plan) Car park	Nurses station outside NICU Staff offices Roof floor	Corridor Nurses station directly outside Other neonatal units attached (partitioned by windows)	Harbour Open plan
Internal Environment (Entrances, Windows, Air Vents, Air-conditioning)	1 row windows 1 row partition windows No air vents 1 main entrance 1 staff room entrance	1 row windows 1 main entrance	2 rows of partition windows 1 row of windows 1 main entrance	2 rows of windows Curtains Low care (partitioned with windows) Isolation room (Partitioned by windows) Equipment room 1 main entrance 1 emergency exit
No of ICU/High Care areas	1 ICU (Beds A-B) 1 High Care (Beds C-D)	1 Isolation cubicle (Bed A) 1 ICU (Beds B-J)	1 ICU (Beds A-F)	1 Isolation cubicle (Bed A) 1 ICU (Beds B-D) 1 High Care (Beds E-I)
Number of beds and occupants	1 ICU (2 beds) (2 occupied) 1 High Care (2 beds) (2 occupied)	1 Isolation cubicle (1 bed) (1 occupied) 1 ICU (9 beds) (9 Occupied)	1 ICU (6 beds) (5 occupied)	1 Isolation cubicle (1 bed) (1 occupied) 1 ICU (3 beds) (2 occupied) 1 High Care (5 beds) (3 occupied)
NICU measurements	41.25m^2	81.42m^2 ICU – 73.21m^2 Isolation – 8.21m^2	77m^2	180m^2
Absorbent/ Reflective Surfaces (Carpets, Curtains, Vents, Plumbing, Pipes)	2 Solid Partitions Curtains Open plan Wooden desk Portable metal trolleys Cardboard bin Plastic bin for sharps	1 Solid Pillar No curtains Wooden desk Portable metal trolleys Cardboard bin Plastic bin for sharps Plastic and metal chairs Fridge	1 Solid Pillar No curtains Carpeted walls Wooden desk Portable metal trolleys Cardboard bin Plastic bin for sharps Plastic and metal chairs	No pillars No curtains Wooden desk Portable metal trolleys Cardboard bin Plastic and metal chairs

	Plastic and metal chairs			
Work areas inside NICU	No nurses station Portable metal trolleys in front of each incubator	1 Nurses station Potable metal trolleys to write on in front of each incubators	1 Nurses station Fixed wooden desk between each incubator	1 Nurses station Portable metal trolleys in front of incubators
Number of wash areas and metal Pedal Bins	1 1	4 9	1 15	2 4
Kitchen/Staff break areas/Toilets	Outside NICU	Outside NICU	Outside NICU	Outside NICU
Number of staff	± 4	± 6	± 6	±5
Staff to occupant ratio	1 is to 1	1 is to 1	1 is to 1	1 is to 1
Shift times, Feeding times, Doctors rounds,	Morning shift (7am-6pm), Night shift (6pm-7am) Feeding time (Every 3 hours / breastfeeding: on demand) Tea breaks (9am to 9:30am) Lunch (12:00pm to 12:30pm), Staff round: 8am, 10am			
Equipment/machines	No intercom No telephone 1 printer in staff room Monitors Ventilators	No intercom 1 telephone 1 printer Monitors Ventilators Radio	No intercom No telephone No printer Monitors Ventilators	No intercom 1 telephone 1 printer Monitors Ventilators Radio

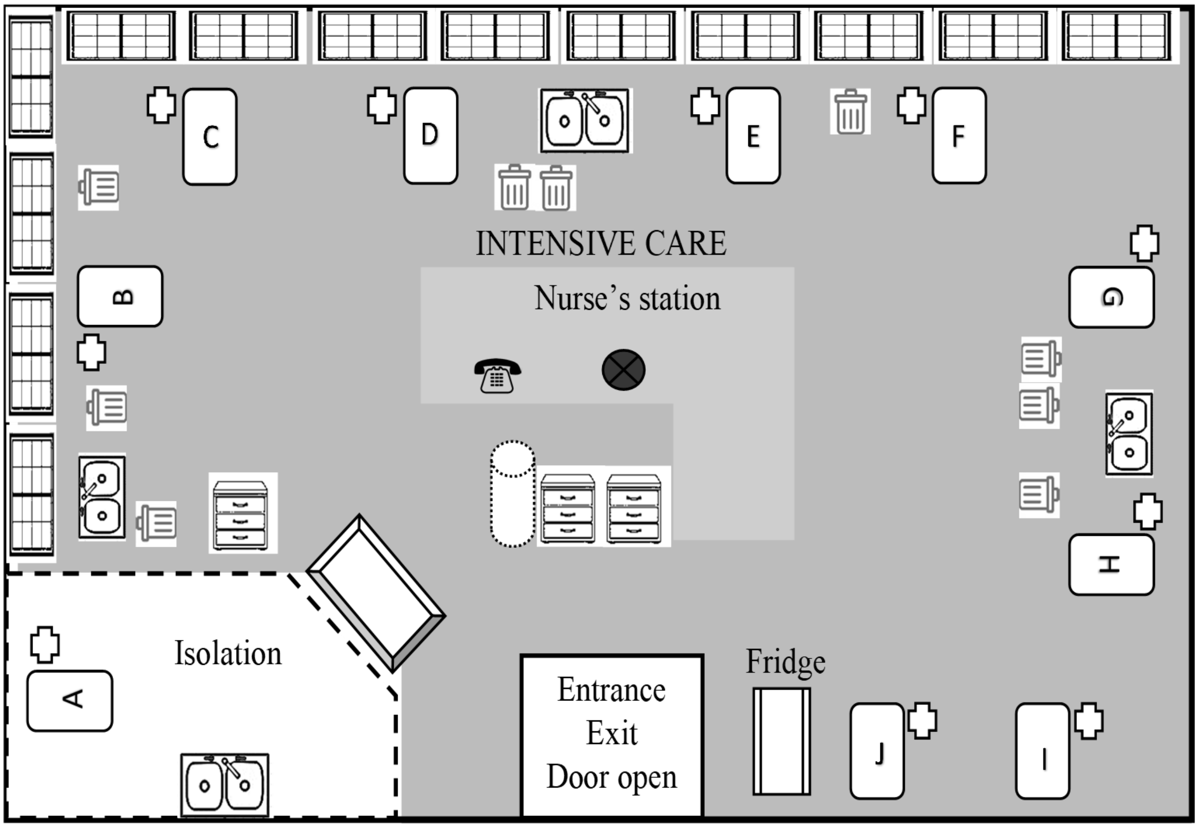
Appendix L1. Key for floor plans

Incubator		Pillar	
Monitors		High partition	
Wash Basin		Low partition	
Window looking outside NICU		Glass partition between units/areas	
Metal bin		Table	
Drawer		Telephone	
Location of SLM			

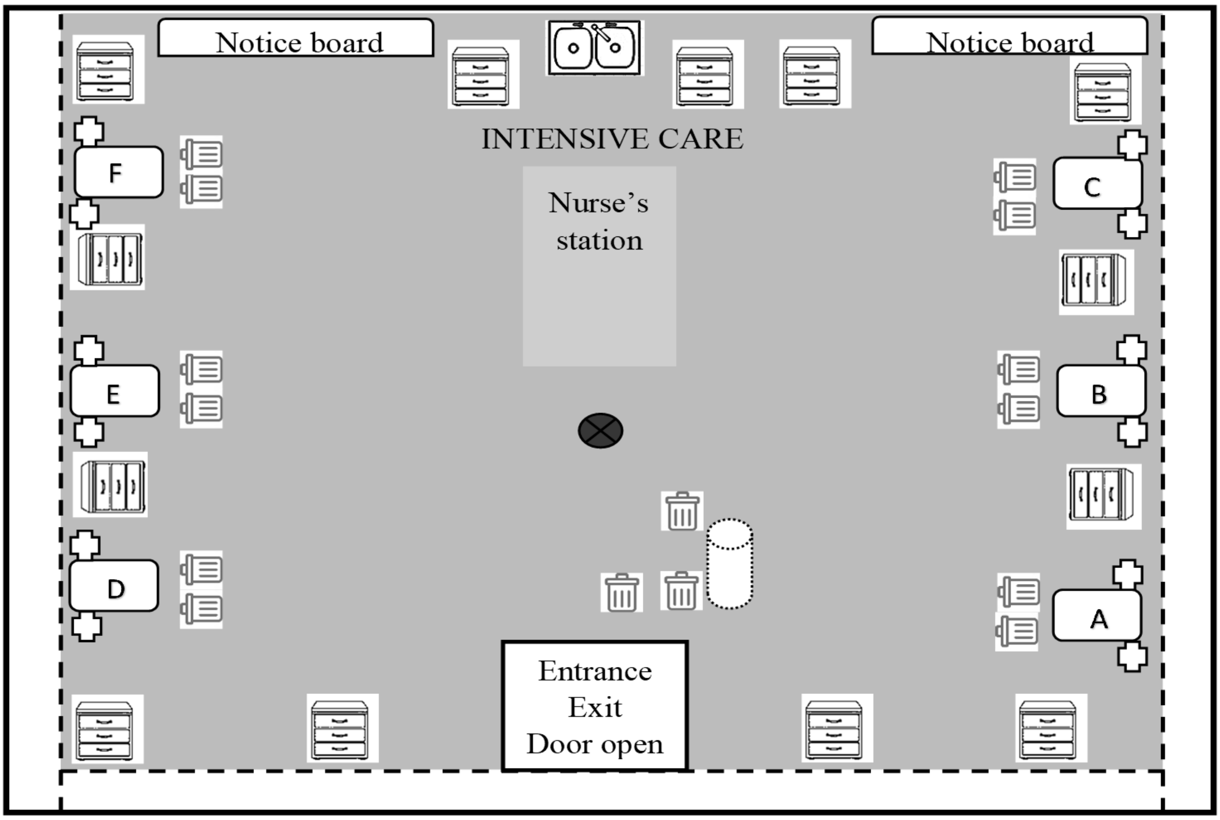
Appendix L2. Floor plan for hospital A



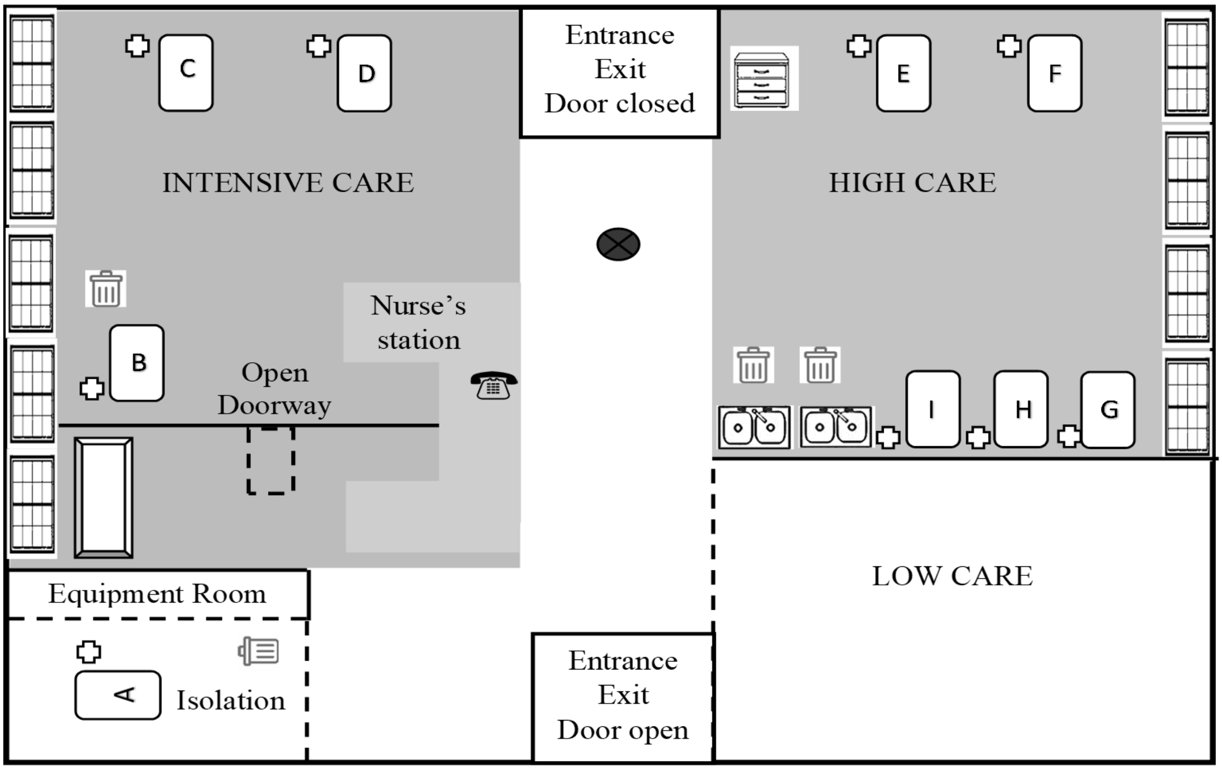
Appendix L3. Floor plan for hospital B



Appendix L4. Floor plan for hospital C



Appendix L5. Floor plan for hospital D



Appendix M1. Calibration certificate for calibrator

sanas
Calibration Laboratory
148
1300

M AND N ACOUSTIC SERVICES (Pty) Ltd
Co. Reg. No: 2012/123238/07 VAT NO: 4000255876 BEE Status: Level 4
P.O. Box 61713, Pierre van Ryneveld, 0045
No. 15, Mustang Avenue
Pierre van Ryneveld, 0045
Tel: 012 689-2007 (076 920 3070) • Fax: 086 211 4690
E-mail: admin@mnacoustics.co.za
Website: www.mnacoustics.co.za

CERTIFICATE OF CALIBRATION

CERTIFICATE NUMBER	*2017-AS-2095*
ORGANISATION	*UKZN WESTVILLE CAMPUS AUDIOLOGY*
CALIBRATION OF	*ACOUSTIC CALIBRATOR*
MANUFACTURER	*CEL*
MODEL NUMBER	*110/2*
SERIAL NUMBER	*288652*
DATE OF CALIBRATION	*06 NOVEMBER 2017*
RECOMMENDED DUE DATE	*NOVEMBER 2018*
PAGE NUMBER	*PAGE 1 OF 3*

This certificate is issued in accordance with the conditions of approval granted by the South African National Accreditation System (SANAS). This Certificate may not be reproduced without the written approval of SANAS and M and N Acoustic Services.

The measurement results recorded in this certificate were correct at the time of calibration. The subsequent accuracy will depend on factors such as care, handling, frequency of use and the amount of different users. It is recommended that re-calibration should be performed at an interval, which will ensure that the instrument remains within the desired limits and/or manufacturer's specifications.

The South African National Accreditation System (SANAS) is member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org

Calibrated by:	Authorised/Checked by:	Date of Issue:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	M. NAUDÉ (SANAS TECHNICAL SIGNATORY)	06 NOVEMBER 2017

Director: Marianka Naudé

Appendix M2. Calibration certificate for sound level meter

sanas
Calibration Laboratory
140
1302

M AND N ACOUSTIC SERVICES (Pty) Ltd

Co. Reg. No: [illegible] VAT NO: [illegible] BEE Status: Level 4

P.O. Box 51713, Pierre van Ryneveld, 0045

No. 15, Mustang Avenue
Pierre van Ryneveld, 0045

Tel: 012 689-2007 (076 920 3070) • Fax: 086 211 4690
E-mail: admin@mnacoustics.co.za
Website: www.mnacoustics.co.za

CERTIFICATE OF CONFORMANCE

CERTIFICATE NUMBER	*2017-AS-2094*
ORGANISATION	*UKZN WESTVILLE CAMPUS AUDIOLOGY*
CALIBRATION OF	*INTEGRATING SOUND LEVEL METER complete with built-in ⅓-OCTAVE/OCTAVE FILTER and ½"MICROPHONE*
MANUFACTURER	*CEL*
MODEL NUMBERS	*450, 495 and 252*
SERIAL NUMBERS	*468811, 002112 and 41172*
SOFTWARE REVISION	*1,09*
DATE OF CALIBRATION	*06 NOVEMBER 2017*
RECOMMENDED DUE DATE	*NOVEMBER 2018*
PAGE NUMBER	*PAGE 1 OF 4*

This certificate is issued in accordance with the conditions of approval granted by the South African National Accreditation System (SANAS). This Certificate may not be reproduced without the written approval of SANAS and M and N Acoustic Services.

The measurement results recorded in this certificate were correct at the time of calibration. The subsequent accuracy will depend on factors such as care, handling, frequency of use and the amount of different users. It is recommended that re-calibration should be performed at an interval, which will ensure that the instrument remains within the desired limits and/or manufacturer's specifications.

The South African National Accreditation System (SANAS) is member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org

Calibrated by:	Authorised/Checked by:	Date of Issue:
C. DE CLERCQ (CALIBRATION TECHNICIAN)	M. NAUDE (SANAS TECHNICAL SIGNATORY)	07 NOVEMBER 2017

Director: Marianka Naudé

Appendix N. Noise measurement form

Hospital:		**Date:**		
Time Interval	**LAeq**	**LAmax**	**LAmin**	**LZpeak**
7:00 – 8:00am				
8:00 – 9:00am				
9:00 – 10:00am				
10:00 – 11:00am				
11:00 – 12:00pm				
12:00 – 1:00pm				
1:00 – 2:00pm				
2:00 – 3:00pm				
3:00 – 4:00pm				
4:00 – 5:00pm				
5:00 – 6:00pm				
6:00 – 7:00pm				
7:00 – 8:00pm				
8:00 – 9:00pm				
9:00 – 10:00pm				
10:00 – 11:00pm				
11:00 – 12:00pm				
12:00 – 1:00am				
1:00 – 2:00am				
2:00 – 3:00am				
3:00 – 4:00am				
4:00 – 5:00am				
5:00 – 6:00am				
6:00 – 7:00am				

Appendix O. Sources of noise checklist

	Hospitals			
Sources of noise	**A (%)**	**B (%)**	**C (%)**	**D (%)**
Alarms of devices				
Monitors, Ventilators				
Human-related noise				
Human vocalisations				
Staff conversations				
Morning prayer/singing				
Crying babies				
Coughing/sneezing				
Staff laughing				
Object noises				
Closing of metal pedal bin				
Switching on tap				
Tearing tissue from dispenser				
Closing of cupboard door				
Cleaning of bins				
Dragging chairs				
Telephone/cell-phone ringing				
Washing utensils in metal sink				
Wheeling of trolley/equipment in NICU				
Foot traffic				
Dropping objects				
Removing tape of boxes in the NICU				
Shuffling/tearing items				
Suctioning a baby				
Nebulising a baby				
Hand clapping by staff				
Noise from radio or cell-phone				
Total				

Appendix P1. Field dairy for hospital A

Hospital A				
Time	Sunday	dBA	Monday	dBA
7h00 - 8h00	Prayer time (Directly outside NICU, Loud, Long lasting)	LAeq (66.0) LAmax (82.9) LAmin (50.8) LZpeak (106.0)	7h15: Nurses busy with administration 7h30: Nurses checking patient monitors 7h30: Dragging of chairs, Cleaning staff present 7h40: Staff laughing, Staff conversation 7h45: Dropping of metal object on the floor (3 m from SLM) (67.1 – 68.1) 7h55: Suctioning no effect (low frequency) no effect on LAeq level Would be best to close the NICU door 7h55: Tearing plastic paper 7h55: Tap opened (no effect on LAeq level)	LAeq (67.1) LAmax (87.7) LAmin (53.3) LZpeak (107.8)
8h00- 9h00	Morning meeting Multiple alarms (High frequency)	LAeq (63.0) LAmax (82.9) LAmin (50.8) LZpeak (106.0)	8h10- 8h30: Prayer time (Loud) LAeq increased (66.0-67.7) 8h10: Suctioning 8h45: Morning meeting Nurses laughing and clapping loudly outside NICU Staff conversation 8h35: Foot traffic in corridor as it is doctor's rounds Nurse closed NICU door, another nurse opened it and didn't close it again 8h40: Doctors rounds 8h55: Staff conversation, loud clapping at nurse's station	LAeq (66.7) LAmax (87.7) LAmin (50.7) LZpeak (107.8)
9h00- 10h00	2 Nurses and 1 doctor present 9h00: Multiple alarms, high frequency 9h05, 9h40: Dragging of chairs X2 9h10: Able to hear babies crying in other sections (Babies begin to cry approaching feeding time) 9h15: Feeding time Tea break 9h45: Bin closed X2 9h40: Staff conversations Windows are open 9h50: Doctor talking on his cell phone at babies' incubator Nurses sneezed X2	LAeq (62.2) LAmax (82.9) LAmin (50.7) LZpeak (106.0)	9h00: Feeding time 9h00: Multiple alarm (low f) 9h00: Staff conversation X2 Laughing X2 9h15: Crumbling of paper 9h20: Tap opened 9h30: Multiple low frequency alarms 9h40: Dragging of metal chairs (mostly done by mothers) 9h50: Loud staff conversation and laughing, nurses told to be quiet by another nurse 9h55: Crying baby 2 nurses present	LAeq (65.7) LAmax (87.7) LAmin (50.7) LZpeak (107.8)

10h00-11h00	10h20: Doctors rounds 10h10: Staff conversation Multiple alarms on (low frequency) 10h05, 10h55: Crying baby X2 10h55: Bin closed	LAeq (61.8) LAmax (82.9) LAmin (50.7) LZpeak (106.0)	10h15: Multiple alarms (med frequency) 10h15, 10h20, 10h30: Staff conversation X4 Staff laughing 10h30: Crying baby (doctor drawing blood)	LAeq (65.0) LAmax (87.7) LAmin (50.7) LZpeak (107.8)
11h00-12h00	11h05: Multiple alarms (High and low frequency) 11h05: Crying baby 11h25, 11h55: Tap opened X2, Crumbling of paper 11h30: Closing of cupboards 11h30, 11h45: Staff conversation X2 Nurses back from tea break as NICU appears busier 11h45: Telephone rings Nurses reported that monitors beep for no reason	LAeq (61.6) LAmax (82.9) LAmin (50.7) LZpeak (106.0)	11h15: Ringing telephone 11h20: Multiple low frequency alarms on 11h30: Dragging metal chairs 11h30: Staff conversation	LAeq (64.9) LAmax (87.7) LAmin (50.7) LZpeak (107.8)
12h00-13h00	2 mothers, 1 nurse present, 2 doctors, 3 babies 12h00: Feeding time 12h15: Nurse pressing button on machine (loud beeps) 12h40; Staff conversation, Staff laughing	LAeq (61.3) LAmax (82.9) LAmin (50.7) LZpeak (106.0)	12h00: Feeding time 12h15: Switching on tap 12h15: Multiple alarms (Low frequency) 12h15: Intern ward round, 15 people in the ward Ward is busy as 3 mothers, 2 nurses and 3 doctors present	LAeq (64.6) LAmax (87.7) LAmin (50.7) LZpeak (107.8)

Appendix P2. Field diary for hospital B

Hospital B				
Time	Sunday	dBA	Monday	dBA
7h00 - 8h00	10 babies 7h10: Multiple beepers on Radio on low volume Bin X1 Tearing paper 7h30: Prayer time (Further away from NICU, Quiet) NICU Bright Entrance door is closed 7h30: Staff conversation 7h35: Alarm (High frequency) Sudden short lasting (65.0dB-67.6dB) Nurses preparing for feeding time at nurse's station in the NICU (63.4dB – 67.7dB)	LAeq (66.1) LAmax (91.9) LAmin (54.6) LZpeak (104.0)	9 babies present, bed C empty 7h00: Cleaning staff present (sometimes bumps into objects, makes a sudden loud noise) 7h10: Morning meeting (outside NICU) No staff activity from 7h15-7h30 7h35: Nurses preparing for feeding time 7h35: Multiple low frequency alarms 7h35: Tearing of plastic 7h40: High frequency alarm -short lasting X3 7h40: Suctioning 6 staff members present (4 nurses, doctor and 1 cleaner) 7h55: Closing of cupboard door X2 7h55: Staff conversation Bins can be closed slowly, depends on the nurses Bin closed (58.1dB-60.4dB)	LAeq (64.4) LAmax (82.3) LAmin (55.5) LZpeak (104.9)
8h00- 9h00	8h00: Feeding time Multiple alarms (High frequency) (LAeq- 66.1dB-71.0dB) High frequency alarm again (70.1dB-74.6dB) 9 people in the ward (3 mothers, 3 doctors, 3 nurses) Doctors rounds Baby has apnoea attack, nurses and doctors rush to baby (no effect on LAeq) 8h30: Cupboard closed (no effect on LAeq) 8h35, 8h55: Bin closed X4 8h40: High frequency alarm X3 (Resuscitation)	LAeq (70.8) LAmax (88.9) LAmin (54.7) LZpeak (109.7)	8h10: Feeding time 16 people present in the ward (7 mothers, 4 nurses, 5 doctors) 8h15: Doctors rounds 25 people in the ward (12 doctors, 5 nurses, 7 mothers, 1 student nurses) LAeq 64.4dB-64.8dB 8h30: High frequency alarm 8h35, 8h40: Crying baby, continuous X2 8h35, 8h40: Bin closed X6 8h35: Staff conversation 8h40: Switching tap on, tearing paper 8h55: Multiple low frequency beepers on 2 nurses and 2 doctors present	LAeq (64.1) LAmax (82.3) LAmin (55.1) LZpeak (104.9)
9h00- 10h00	9h00: Tea break 9h10: Tearing of drip packaging (LAeq-64.2dB- 65.3dB) Ward is quieter (1 Doctor and 1 nurse present) 9h50: Bin closed (LAeq 63.1dB-63.6dB) (LAmax 80.6dB-88.5dB) (LZpeak 109.7dB-110.1dB)	LAeq (63.1) LAmax (80.6) LAmin (55.3) LZpeak (110.1)	9h00: Tea break 9h15, 9h50: Bin closed X3 9h50: Staff conversation 9h50: Cupboard door closed 9h55: Dropped metal object on floor 7 people present (4 doctors and 3 nurses)	LAeq (64.0) LAmax (89.3) LAmin (55.1) LZpeak (109.8)

10h00-11h00	7 people in the ward, Tea break is over 10h00: 10h30: Multiple alarms (intermittent) 10h:40: Wheeling of trolleys outside NICU X3 Babies cry frequently in the general ward, the general ward is busier than the NICU, so it is good that it is separate, it is also good that the mothers wash up outside NICU, less noisy activities such as the closing of bins	LAeq (63.1) LAmax (81.9) LAmin (55.0) LZpeak (108.0)	10h10: Multiple alarms 10h10: Suctioning (Baby E) 10h15: Printer (low), Crying baby 10h15, 10h40: Tap opened X3 Tearing of paper 10h20: Bin closed X2 10h20: Dragging chairs 10h55: Multiple low frequency beepers on 10h55: Staff conversation Doctor talking on cell phone 4 staff present	LAeq (63.6) LAmax (89.3) LAmin (55.1) LZpeak (109.8)
11h00-12h00	11h00: Feeding time 5 mothers and 2 nurses present Nurses reported that they used noise control methods like plastic chairs, monitors are on the lowest level, telephone on the lowest level, sometimes they cover incubators Tried Quiet time protocol but did not work every time as it is dependent on the babies' condition 11h20, 11h50, 11h55: Bin closed X4 11h40: Tap opened X6 Switching on the tap is not noisy Tearing of paper is noisy, depending how hard you pull on it 11h40: Nurses laughing X3 11h45: High frequency alarm, short lasting X2 (LAeq 64.0 – 64.4) 11h55: Staff conversation 11h55: Tearing of paper	LAeq (63.3) LAmax (83.5) LAmin (55.0) LZpeak (108.0)	11h00: Feeding time 4 mothers and 2 doctors present 11h15: Low frequency beepers on 11h30: High frequency alarm, short lasting X3 (Apnoea monitor) 11h30: Crying baby 11h35: Alarm high frequency long lasting	LAeq (63.8) LAmax (89.3) LAmin (54.7) LZpeak (109.8)
12h00-13h00	12h00: Lights switched off due to it been too hot in the NICU 12h00, 12h10: Multiple alarms (High frequency) X4 12h00: Staff conversation X2 (Conversation is always between staff and not the mothers) 12h10: Bin closed X2 12h10: Tearing paper X2 12h40: Suctioning 12h45: Cupboard closed 12h45: Opened tap, tearing tissue 12h45: Dropped object on the ground 12h55: Cleaning staff	LAeq (63.7) LAmax (91.4) LAmin (55.0) LZpeak (111.8)	12h00: Lunch time 1 nurse present 12h15: Multiple low frequency beepers on 12h45: Doctor talking on cell phone Bin closed (4m from SLM) (66.9dB-67.1dB) (67.7dB-68.3dB) Bin at head side of baby	LAeq (63.5) LAmax (89.3) LAmin (54.3) LZpeak (109.8)

Appendix P3. Field diary for hospital C

Hospital C				
Time	Sunday	dBA	Monday	dBA
7h00 - 8h00	5 babies present, and 4 nurses and 1 cleaner Cleaning staff present NICU semi bright, natural light from windows Multiple alarms on (Low frequency)	LAeq (61.2) LAmax (82.1) LAmin (52.3) LZpeak (102.1)	7h00: Prayer time (outside NICU, loud) (20 nurses), NICU door open LAeq 63.3dB -72.7dB after prayer 7h10: Multiple alarms on (High frequency), Nurses inattentive to alarms 7h15: Morning meeting Cleaning staff Loud staff conversations 6 nurses and 5 babies present Loud shift of staff Loud conversations outside NICU X2 7h20: High frequency alarm 7h25: Nurse turned alarm off after 5 minutes 7h30: Bin closed, tearing of paper Tap opened X2 7h35: Staff conversation X2 7h35: Washing utensils 7h35, 7h45: Closing cupboard X7 (nurses busy changing incubator sheets) 7h45, 7h50: Bin closed X5 Removing tape of box -loud Crying baby (because nurses is wiping him) Shuffling paper X2 7h45, 7h55: High f alarm X4 7h50: Telephone ringing X3 7h50: Suctioning 7h55: Dragging chairs X2	LAeq (67.5) LAmax (81.6) LAmin (53.1) LZpeak (104.2)
8h00- 9h00	8h20: Tap opened X2, Coughing X2 8h30: Closing wooden cupboards X2 8h40: Staff conversation Someone talking to nurses from outside 8h40: Dragging of chairs	LAeq (60.6) LAmax (82.1) LAmin (52.3) LZpeak (102.1)	Doctors rounds (3 doctors, 5 nurses) 8h00, 8h50: Bin closed X4 8h00: High frequency alarm X2 Staff conversation loud 8h00, 8h25: Cupboard closing X3 8h10: Paper shuffling X2 8h15: Suctioning 8h30, 8h50: Tap opened X3 8h30: Tearing paper X3 8h30: 8h45: Dragging of chairs Ringing telephone Staff conversation outside NICU Bin closed X2	LAeq (66.0) LAmax (82.8) LAmin (53.1) LZpeak (106.4)
9h00- 10h00	2 doctors, 2 Nurse and 1 mother present 9h00: Tea break 9h00: Feeding time	LAeq (59.5) LAmax (82.1)	9h00: Tea break 9h00: Feeding time 9h00: Bin closing X2 9h10: Tap opened X2	LAeq (65.0) LAmax (84.8)

	9h10: Doctors rounds 9h15: Multiple low frequency beepers on 9h35, 9h55: Tap opened X4, tearing paper 9h35: Closing bin 1 nurse and 1 mother present	LAmin (52.0) LZpeak (102.1)	9h30: Staff conversation 2 nurses and 2 mothers present 9h45: Tearing paper X2	LAmin (53.1) LZpeak (109.2)
10h00-11h00	Alarms are turned off quickly Doctors turn on bed light instead of keeping NICU light on Nurses on tea break 2 nurses present 10h10: Multiple low f beepers 10h55: Closing bin, switching tap on, tearing paper (Nurses are closing bin slowly, so it is not making a sound)	LAeq (58.9) LAmax (82.1) LAmin (52.0) LZpeak (102.1)	Nurses still on tea break Ward quieter 2 nurses talking quietly at the nurse's desk	LAeq (64.0) LAmax (84.8) LAmin (53.1) LZpeak (109.2)
11h00-12h00	11h00: Doctors rounds 6 people in the ward 2 doctors, 4 nurses 11h10, 12h00: Bin closed X3 11h10: Dragging chairs on the floor X2 1h15: Staff conversation 11h15: Staff laughing 11h15: Wheeling of trolley outside NICU 11h20: Tap opened After doctor's rounds (58.9dB-59.7dB)	LAeq (59.7) LAmax (82.1) LAmin (52.0) LZpeak (103.6)	11h00: All nurses back from tea break 11h05: Tap opened, Tearing paper Paper shuffling 11h15: Staff conversation 6 nurses present 11h30: HOD present	LAeq (63.9) LAmax (84.8) LAmin (53.1) LZpeak (109.2)
12h00-13h00	12h00: Feeding time 2 nurses and 1 mother present 12h00: Metal object dropped LZpeak (103.6dB-116.0dB) LAmax (82,1dB-84,5dB) 12h25: Coughing 12h50: Staff conversation 12h50: Tap opens, tear paper 12h50: High frequency alarm	LAeq (59.6) LAmax (84.5) LAmin (52.0) LZpeak (116.0)	12h00: Feeding time Busy in the ward 4 nurses and 3 mothers present Bins been cleaned 12h10: Bins closed LZpeak 103.9dB-104.5dB, Next to SLM Tap opened 12h15: Tearing paper Bin closed X3	LAeq (64.0) LAmax (84.8) LAmin (53.1) LZpeak (109.2)

Appendix P4. Field diary for hospital D

Hospital D				
Time	Sunday	dBA	Monday	dBA
7h00 - 8h00	Prayer time (Inside NICU, low intensity, short lasting) Radio on low volume Cleaner changing bins 7h40: Bin closed X1 4 nurses, 2 doctors and 1 cleaner present	LAeq (62.5) LAmax (78.4) LAmin (53.1) LZpeak (100.1)	Prayer time (inside NICU, quiet) Cleaning staff present	LAeq (63.2) LAmax (85.0) LAmin (51.0) LZpeak (110.0)
8h00-9h00	8h00: Feeding time (5 mothers present) 8h00: Dropping stapler (LZpeak-100.1dB-105.6dB) 6 m away from SLM 8h05: Cleaning staff 8h10: Dropping metal stool (LAeq 62.7dB-64.1dB) (LZpeak-105.6dB-110.8dB) (LAmax 80.9dB-90.8dB) Doctors round 8h10: Staff conversation X3 Multiple low f alarms on 8h15: Staff laughing 8h20: Loud doctors present 8h45: Telephone rings X2 8h50: High frequency alarm	LAeq (63.3) LAmax (90.8) LAmin (50.8) LZpeak (110.8)	8h00: Feeding time 2 doctors, 4 nurses, 4 mothers and 1 cleaner present 8h05: High f alarm short lasting 8h15: Tap open, tearing paper X2 8h20: Resuscitation 8h30: Staff conversation, staff laughing 8h35: Pulling tape of a box (loud) 8h45: Multiple low f beepers on 8h50: High frequency alarm 8h55: Ringing telephone	LAeq (63.0) LAmax (85.0) LAmin (50.3) LZpeak (110.0)
9h00-10h00	Nurses tea break 2 nurses present 9h35, 9h50: High f alarm X2 9h35: Staff conversation X2 1 doctor and 1 nurse present 9h35: Wheeling of trolley	LAeq (62.0) LAmax (90.8) LAmin (50.6) LZpeak (110.8)	9h05: Multiple alarms (high frequency) because doctor was treating patient Doctor deactivated alarm after 5 minutes 9h05: Dragging of chairs 9h05, 9h10, 9h15, 9h50: Staff conversation X4 9h10: Crying baby 9h15: Multiple low f alarms 9h15: Shuffling of paper 9h20: High f alarm 9h30: Closing bin This shift of doctors is more quiet 9h45: Tap opened X3, Tearing paper X3 9h45, 9h50: Staff laughing X3 9h45: Telephone rings X2	LAeq (62.2) LAmax (85.0) LAmin (50.2) LZpeak (110.0)
10h00-11h00	Nurses still on tea break 1 doctors and 1 nurse present 10h20: Radio on (Loud intensity) 10h20, 10h40: Multiple alarms (High f) X3 10h30: Nurse deactivates alarm 10h40: Staff conversation	LAeq (61.5) LAmax (90.8) LAmin (50.6) LZpeak	10h30: Staff conversation X3 4 nurses and 3 doctors 10h40: Staff conversation Some staff suggest that SLM should be hidden 10h50: Doctors rounds 5 doctors and 1 nurse present	LAeq (61.5) LAmax (85.0) LAmin (50.2) LZpeak

		(110.8)		(110.0)
11h00-12h00	11h00: Feeding time 11h00, 11h20: Suctioning X2 11h10,11h55: Staff conversation X2 11h15; X-Ray staff present 11h20: Tap opened, Paper tearing 5 mothers 2 nurses and 1 doctor present	LAeq (61.1) LAmax (90.8) LAmin (50.6) LZpeak (110.8)	11h00: Feeding time 11h05: Suctioning 11h05, 11h55: Tap open X3, Tearing paper X3 11h05: Wheeling of trolley 5 doctors, 2 nurses and 7 mothers present 11h15, 11h45: Alarm high f X2 11h50: Suctioning 11h50: Staff conversation Staff laughing 11h55: Ringing telephone	LAeq (61.1) LAmax (85.0) LAmin (50.2) LZpeak (110.0)
12h00-13h00	12h05, 12h30: Multiple alarms (High and low f) 12h40. 12h55: Ventilator alarm (High f) X2 12h50: Staff conversation	LAeq (61.1) LAmax (90.8) LAmin (38.6) LZpeak (110.8)	12h10: Staff meeting at nurse's station, patient care discussion 2 doctors and 4 nurses present 12h15, 12h45: High frequency alarm X2 12h20: Staff conversation X4 12h40: Meeting is over 12h45: X-ray department 12h50: Crying baby	LAeq (61.1) LAmax (85.0) LAmin (50.2) LZpeak (110.0)

Appendix Q. Noise reminder poster

PLEASE DO NOT DISTURB
BABIES ARE RESTING

- Please maintain a quiet and calm environment, our babies are trying to rest and recover
- Please speak softly in the NICU
- Please try to close bins quietly
- Please do not drag chairs across the floor
- Please close incubator and cupboard doors quietly
- Please place objects on the table quietly
- Please do not place objects on the incubator
- Please try to turn alarms off quickly
- Please encourage cleaning staff to maintain a quiet environment in the NICU
- Please turn telephones on a low ring tone
- Staff members and caregivers: please turn personal cell phones on silent when in the NICU
- Please keep the NICU door closed to reduce noise levels
- Please encourage mothers to bond with and speak directly to their babies

Thank you for your kind cooperation