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Noise measurements in an acute Australian hospital

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ABSTRACT

Many studies have shown that hospital staff and patients are subject to noise levels in excess of those specified in the World Health Organization (WHO) guidelines. This article presents the results of a single-centre study of noise in four wards in an acute hospital in Adelaide, Australia. The study measured noise in multi-bed bays, as well as nurse stations, and involved continuous noise monitoring between one and three days. For 4-bed and 6-bed patient bays, as well as nurse stations, the maximum, minimum and average equivalent 1-minute A-weighted sound levels were relatively constant from 22:00 until 06:00, increase from 06:00 until 09:00, remain raised until 18:00, and then decrease from 18:00 until 22:00. Measured average equivalent A-weighted noise levels for nurse stations and patient rooms were 56.6 dB(A) and 54.8 dB(A) respectively. Noise levels were higher in the 6-bed bays compared to the 4-bed bays with average equivalent A-weighted noise levels of 55.7 and 54.3 dB(A) respectively. The results were consistent with similar hospital studies, with noise levels exceeding WHO guidelines for patient comfort.

1 INTRODUCTION

Noise in a hospital setting can be problematic in a number of ways. Noise levels have been known to influence patient rest (Nightingale, 1969) and recovery, thereby potentially contributing to readmissions (Krumholz, 2013), a repeat admission to the hospital within 28 days of discharge. However, there are also concerns about the ease and intelligibility of communication between hospital staff (Ryherd et al., 2013). Additionally, high noise levels contribute to healthcare provider fatigue, and loss of concentration (Salandin et al., 2011), which could lead to errors (Joseph and Ulrich, 2007) and impact on patient safety. The WHO guidelines specify that the A-weighted equivalent (LA_{eq}) sound level should not exceed 35 dB(A) in locations where patients are treated or observed, and should have as few as practicable events with instantaneous levels exceeding 40 dB(A) so as to prevent sleep disturbance (Berglund et al., 1999). However, these levels are rarely, if ever met; the review of hospital noise studies of Busch-Vishniac et al. (Busch-Vishniac et al., 2005) found that none of the sites assessed in the reviewed studies met the WHO guidelines, and concluded that noise in the hospital environment is a universal problem.

To date, most research into noise in hospital settings has focused on intensive care units (ICUs) and emergency departments, as these areas are perceived to be particularly "noisy". There is a relative scarcity of published data on noise levels in hospital wards, where most patients spend the majority of their hospital stay (Shield et al., 2016). The present study therefore investigates noise in four wards comprising both medical and surgical environments, including multi-bed bays of 4 and 6 beds per room, and nurse stations, where nurses and other health care staff conduct their administrative work, such as discussing patient care and updating medical records.

2 MATERIALS AND METHODS

2.1 Study Setting

This single-centre study of four wards was located within a major metropolitan hospital in Adelaide, South Australia. This study of noise levels was part of the first stage of a larger study examining the transition of that hospital into a newly built hospital in which patients are accommodated in rooms with a single bed. The four wards in the study hospital, which was founded in the mid-1800s and progressively redeveloped since, consist of predominantly multi-bed wards in medical care and surgical care and cover different clinical specialties and patient groups including general medicine neurology, high volume surgical unit, orthopaedics and surgical care, and stroke (medical care). These wards were chosen as they represent a cross section of the main patient groupings with a mix of patient bedroom configurations.

2.2 Measurement Apparatus and Methodology

Sound levels were measured using a total of six noise loggers; two Brüel & Kjær Model 2250, three Casella Model CEL-633, and one RION Model NL42. Each ward was investigated for periods of one to three days, with a logger in the nurse station(s) and the remainder deployed to patient rooms. In nurse stations, a logger was deployed as close as practicable to the centre of the room; in patient rooms a logger was deployed to be near patients' beds without disrupting their care or equipment. In all instances positioning of the loggers required careful consideration; ensuring staff were confident that the equipment would not impede patient care, would maintain equipment security, and to ensure the equipment was positioned to collect the most representative data possible. A summary of the configuration of each ward and the measurement locations is provided in Table 1.

Table 1: Details of ward and measurement locations

Hospital Details				
Ward	X1	X2	X3	X4
Ward type	General medicine neurology, medical care	Orthopaedic, surgical care	High volume surgical unit, surgical care	Stroke, medical care
Ward configuration	2 x Nurse station 2 x 6-bed bays 2 x 4-bed bays 7 x 1-bed room	2 x Nurse station 2 x 6-bed bays 2 x 4-bed bays 7 x 1-bed room	2 x Nurse station 2 x 6-bed bays 2 x 4-bed bays 8 x 1-bed room	1 x Nurse station 3 x 4-bed bay 5 x 1-bed room

Measurement locations and periods								
	Location	Period (hrs)	Location	Period (hrs)	Location	Period (hrs)	Location	Period (hrs)
4-bed bays			4-bed bay #1	22.0	4-bed bay #1	48.3	4-bed bay #1	68.9
			4-bed bay #2	50.8	4-bed bay #2	47.6	4-bed bay #2	68.7
							4-bed bay #3	69.1
6-bed bays	6-bed bay #1	49.5	6-bed bay #1	50.9	6-bed bay #1	48.2		
	6-bed bay #2	48.8						
Nurse stations	Station #1	49.8	Station #2	50.2			Station #1	48.5
	Station #2	49.6						

The loggers took 1-minute long averages, recording the A-weighted equivalent sound level (LA_{eq}), fast response time maximum (LAF_{max}), and minimum (LAF_{min}) levels. Additionally, Z-weighted one third octave band sound levels across octave bands with centre frequencies from 6.3 Hz to 20 kHz were averaged over the total logging period. Noise loggers were deployed in ruggedized cases which served to prevent interference with the logger, and to store batteries used to power the loggers when convenient access to mains power was unavailable. Microphones were fitted with open-cell foam microphone windshields and were fixed at approximately 1.5 m above ground level, to approximate the position of a patient in bed.

3 RESULTS AND OBSERVATIONS

The sound level results, specifically the A-weighted equivalent, fast response time, maximum and minimum levels for each measurement location are given in Table 2, along with calculated means and standard deviations (SD). Results are also presented for the quantities such as the average of the 1-minute A-weighted equivalent levels across a sampling period $(LA_{eq})_{mean}$; the (acoustic) mean and maximum of the 1-minute A-weighted maximum levels across a sampling period, given by $(LAF_{max})_{mean}$ and $(LAF_{max})_{max}$, respectively; and the (acoustic) mean and minimum of the 1-minute A-weighted minimum levels across a sampling period, given by $(LAF_{min})_{mean}$ and $(LAF_{min})_{min}$, respectively.

Table 2: Sound level period average results and statistical information

Location	Recording time [hrs]	$(LA_{eq})_{mean}$	$(LAF_{max})_{max}$	$(LAF_{min})_{min}$	$(LAF_{max})_{mean}$	$(LAF_{min})_{mean}$
		[dB(A) re 20 μPa]				
Bedded Bays:						
Ward X1 6-bed bay #1	49.5	56.6	92.4	29.6	73.3	43.0
Ward X1 6-bed bay #2	48.8	57.1	95.2	28.3	71.5	46.0
Ward X2 4-bed bay #1	22.0	52.4	89.6	29.0	70.5	43.6
Ward X2 4-bed bay #2	50.8	55.0	93.4	27.4	71.0	47.2
Ward X2 6-bed bay #1	50.9	54.0	90.4	26.6	69.9	47.4
Ward X3 4-bed bay #1	48.3	55.6	95.4	34.8	74.5	42.9
Ward X3 4-bed bay #2	47.6	52.0	95.5	25.8	69.3	36.8
Ward X3 6-bed bay #1	48.2	55.0	93.6	25.2	70.6	41.7
Ward X4 4-bed bay #1	68.9	56.3	94.8	38.2	70.7	44.8
Ward X4 4-bed bay #2	68.7	56.2	96.1	39.5	73.9	43.7
Ward X4 4-bed bay #3	69.1	52.7	87.8	41.3	68.8	43.6
Mean	**52.1**	**54.8**	**93.1**	**31.4**	**71.3**	**43.7**
Standard deviation	**12.9**	**1.7**	**2.6**	**5.6**	**1.8**	**2.8**
Nurse Stations:						
Ward X1 nurse station #1	49.8	59.8	98.8	32.9	76.6	49.3
Ward X1 nurse station #2	49.6	56.9	92.4	32.5	73.6	46.6
Ward X2 nurse station #2	50.2	60.0	102	30.9	76.8	42.9
Ward X4 nurse station #1	48.5	56.0	92.0	38.3	73.1	42.6
Mean	**49.5**	**58.2**	**96.3**	**33.6**	**75.0**	**45.3**
Standard deviation	**0.6**	**1.8**	**4.3**	**2.8**	**1.6**	**2.8**

The $(LA_{eq})_{mean}$ was 54.8 ± 1.7 (SD) dB(A) across 11 of the bedded bays and 58.2 ± 1.8 dB(A) across the four nurse stations (Table 2). Comparing other measures also demonstrated very similar noise profiles between patient areas and nurse stations, for example the $(LAF_{max})_{max}$ was 93.1 ± 2.6 and 96.3 ± 4.3, respectively (Table 2). The $(LA_{eq})_{mean}$ values for the 6-bed bay patient rooms was slightly higher compared to the 4-bed, with values of 55.7 ± 1.3 dB(A) and 54.3 ± 1.7 respectively.

The noise data was also averaged across day-time (07:00-23:00) and night-time (23:00-07:00) as per WHO guidelines (Berglund et al., 1999) (Table 3). Night-time was consistently quieter than day-time. The nurses stations had higher noise levels than the patient rooms across all considered metrics, and the 6-bed bay patient rooms had higher noise levels than the 4-bed patient rooms for all metrics except for $(LAF_{max})_{mean}$, which was an average 0.4 dB(A) lower for the 6-bed bay patient rooms than the 4-bed patient rooms.

The 1-minute averaged sound level results, across a 48 hour period, for the ward X3 6-bed bay #1, and across a 72 hr period for the ward X4 4-bed bay #2 are given in Figures 1 and 2 respectively. Other measurement locations (results not shown) show similar trends. The LAF_{min} level increases from 06:00 until 18:00, decreases from 18:00 till 22:00, and stays relatively constant from 22:00 until 06:00. The LA_{eq} levels are relatively constant from 22:00 until 06:00, increase from 06:00 until 09:00, remain raised until 18:00, and then decrease from 18:00 until 22:00. The LAF_{max} levels follow the same overall trend as the equivalent levels, increasing from 06:00 until 09:00, remaining in a raised state until 18:00, then decreasing from 18:00 till 22:00, where they remain relatively constant until 06:00. LAF_{max} peaks over 70 dB(A) multiple times between 24:00 and 06:00.

The 1-minute averaged sound level results, across a 48 hour period, for the ward X1 nurse station #1 are given in Figure 3. Compared to the patient wards, it can be seen that the nurses station, although also exhibiting LAF_{min} level decreases for around an 8 minute period at the beginning of the hour for much of the day, experienced smaller variation in both the LAF_{min} and LA_{eq} noise levels between day and night. LAF_{max} peaks over 70 dB(A) multiple times over 24 hours. Figures 4 and 5 give the one-third octave band A-weighted sound levels along with overall sound pressure level (OASPL) for the Ward X3 6-bed bay, and the Ward X1 nurse station respectively. The spectra are very similar in shape, being relatively flat between the 63 and 1000 Hz bands, having somewhat raised levels at frequencies below 63 Hz, and rolling off slowly with increasing frequency above 1000 Hz.

Table 3: Day-night periods sound level results

Location	Day-time			Night-time		
	$(LA_{eq})_{mean}$	$(LAF_{max})_{mean}$	$(LAF_{min})_{mean}$	$(LA_{eq})_{mean}$	$(LAF_{max})_{mean}$	$(LAF_{min})_{mean}$
	[dB(A) re 20 μPa]					
Bedded Bays:						
Ward X1 6-bed bay #1	57.8	74.0	43.9	51.9	71.2	40.4
Ward X1 6-bed bay #2	57.4	72.9	46.5	49.3	65.5	44.5
Ward X2 4-bed bay #1	53.8	71.6	44.2	48.3	67.3	42.4
Ward X2 4-bed bay #2	56.2	72.5	47.5	49.3	61.4	46.5
Ward X2 6-bed bay #1	55.1	71.2	47.8	48.7	63.0	46.6
Ward X3 4-bed bay #1	56.8	75.6	43.6	50.7	70.6	41.2
Ward X3 4-bed bay #2	53.3	71.0	37.7	41.5	59.7	34.3
Ward X3 6-bed bay #1	56.4	72.1	43.0	47.4	62.6	36.3
Ward X4 4-bed bay #1	57.6	72.1	46.2	45.9	64.8	39.8
Ward X4 4-bed bay #2	57.5	74.9	44.7	51.4	71.2	41.1
Ward X4 4-bed bay #3	54.2	69.5	44.0	49.6	67.0	42.7
Mean	**56.0**	**72.5**	**44.5**	**48.5**	**65.9**	**41.4**
Standard deviation	**1.6**	**1.7**	**2.6**	**2.7**	**3.8**	**3.6**
Nurse Stations:						
Ward X1 nurse station #1	60.8	77.5	49.8	54.5	73.9	47.9
Ward X1 nurse station #2	58.3	74.9	47.2	50.9	68.0	45.1
Ward X2 nurse station #2	61.4	77.6	43.8	51.9	71.2	40.4
Ward X4 nurse station #1	57.8	74.1	43.2	51.2	69.8	40.9
Mean	**59.6**	**76.0**	**46.0**	**52.1**	**70.7**	**43.6**
Standard deviation	**1.6**	**1.5**	**2.7**	**1.4**	**2.2**	**3.1**

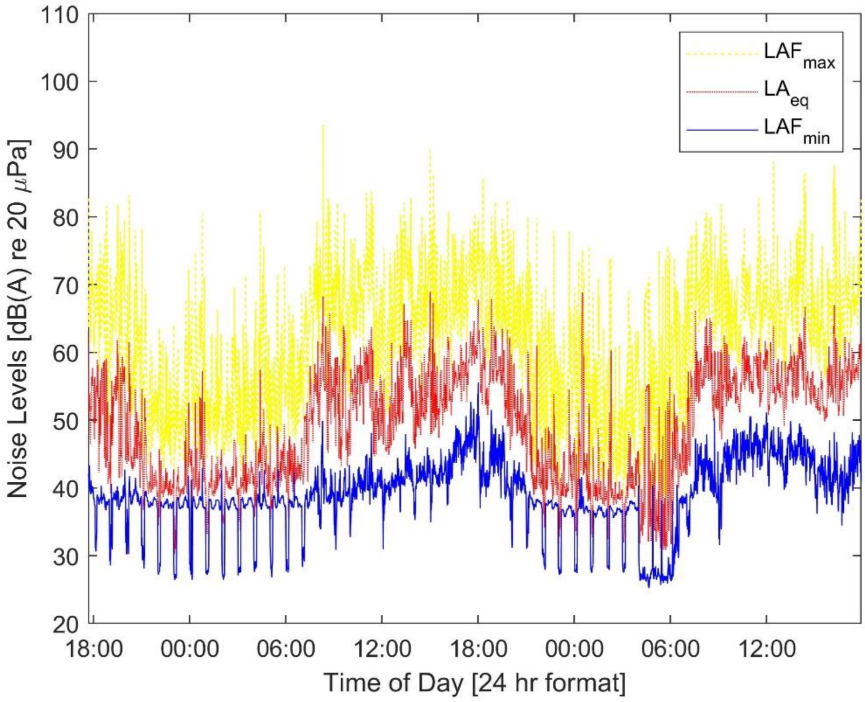

Figure 1: Ward X3 6-bed bay #1 1-minute average sound level results for a 48 hour period

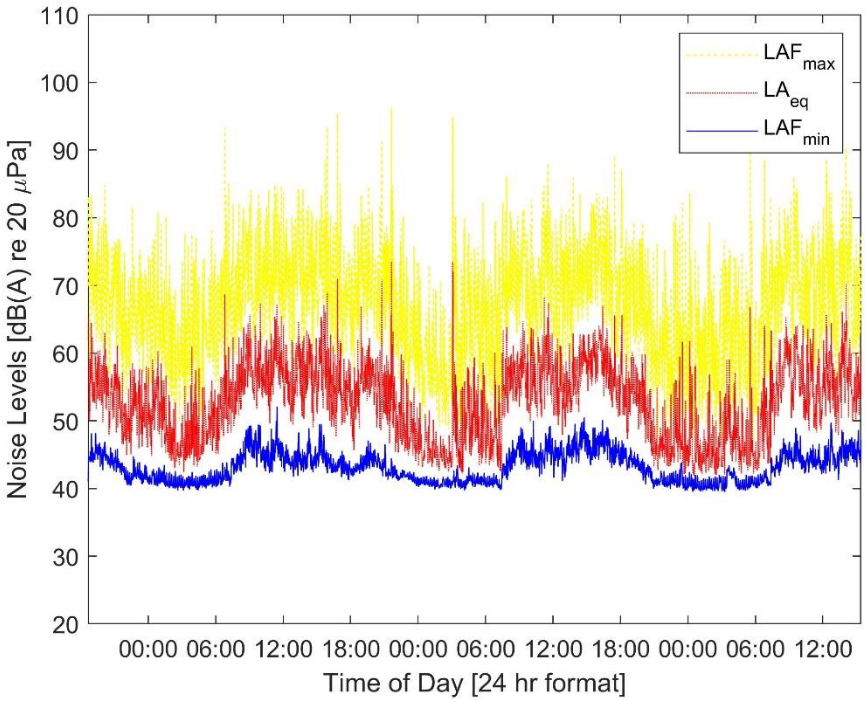

Figure 2: Ward X4 4-bed bay #2 1-minute average sound level results for a 72 hour period

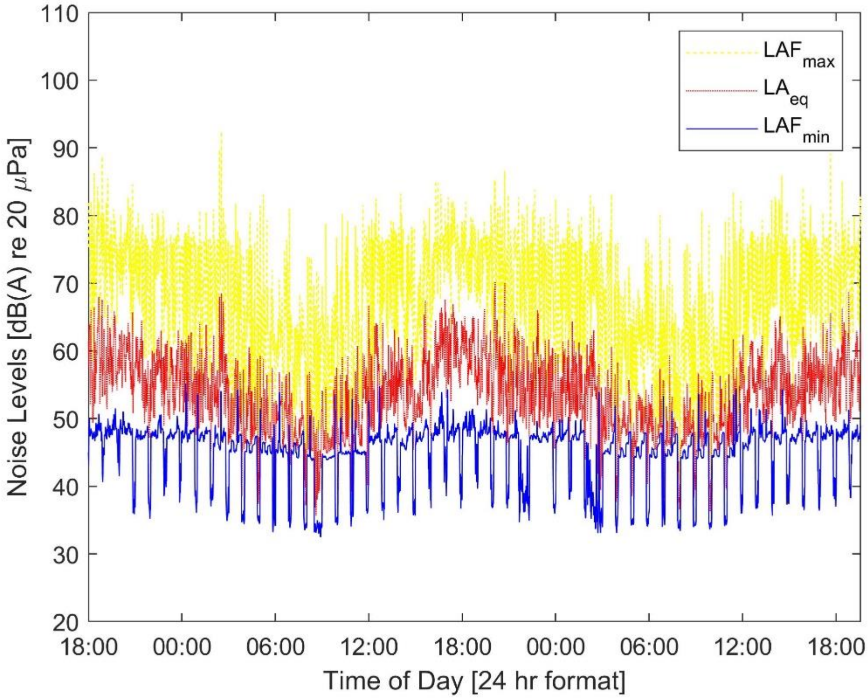

Figure 3: Ward X1 nurse station #1 1-minute average sound level results for a 48 hour period

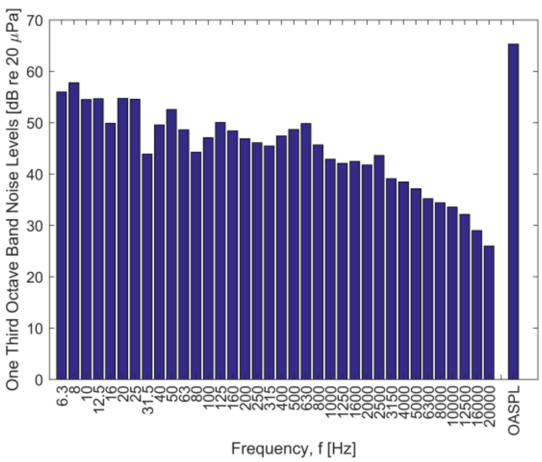

Figure 4: Ward X3 6-bed bay one-third octave band sound levels

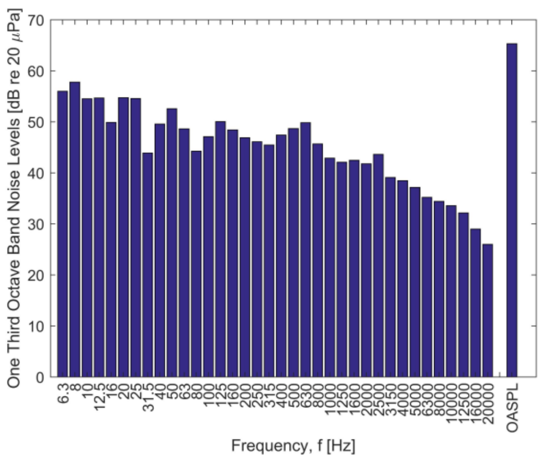

Figure 5: Ward X1 nurse station one-third octave band sound levels

4 DISCUSSION

The present study has demonstrated noise levels in both patient and staff settings well in excess of the WHO Guidelines (Berglund et al., 1999) (both the general LAeq limit of 30 dB(A) and the LAmax limit of 40 dB(A) during the night, to prevent sleep disturbance) and the Australian Standards (AS/NZS 2107:2016) (LAeq limits of 40 and 45 dB(A) for multi-bed patient rooms and nurse stations respectively).

Poor sleep quality has been widely reported for patients in hospitals (Fillary et al., 2015), and exposure to noise at nighttime is a major contributor to poor sleep. For example, exposure to average nighttime noise levels of 50 dB is associated with significantly less sleep in medical ward patients (Yonder et al., 2012). A range of other negative physical effects of hospital noise on patients' physiological well-being have also been documented, including increased blood pressure and heart rate (Lusk et al., 2004), increased length of stay (Fife and Rappaport, 1976) and increased salivary cortisol (Ryherd et al., 2013). Inadequate communication, speech intelligibility and cognition have also been associated with noise in hospitals (Pope et al, 2013), potentially impacting on both patients and staff. Nurses perceive a link between increased noise levels and their stress levels, reporting symptoms such as irritation, fatigue and tension headaches (Ryherd et al., 2012). Although the non-hospital literature suggests a link between environmental sensory overload and task performance disruption, the hospital literature is less definitive (Ryherd et al., 2012). Healthcare staff perceive noise as negatively impacting their job performance, including quality of work, concentration, vigilance, and communication (Ryherd et al., 2012).

Satisfaction with hospital noise levels (ie having a "quiet room") received the lowest rating by patients of eight quality of care measures in the USA (Jha et al., 2008). This finding is mirrored in the UK by inpatient surveys that links noise from staff and other patients to poor patient satisfaction (Fillary et al., 2015). Interventions to improve the problem of noise in hospitals were recently summarised as targeting: staff education and behaviour modification, care organisation and environmental solutions. Blocking of sound through the use of closed doors on single rooms needs to be balanced against the need to allow staff to provide optimal care (Fillary et al., 2015). A few UK hospitals have moved to mainly or exclusively single room designs to block noise (Fillary et al., 2015; Crocker et al., 2004); while in the US Boston General Hospital has installed sliding glass doors to effectively block sounds while still allowing easy observation of patients (Fillary et al., 2015). Although these interventions should lead to lower noise levels for patients, empirical studies in single bed rooms are currently lacking.

Many of the previous noise surveys have been criticised for a lack of clarity with regard to noise measurement parameters used (Shield et al., 2016). Results for average equivalent noise level are in line with those of other studies measuring noise in adult medical and surgical wards (see Table 4), wards where patients spend the majority of their hospital stay. However, the maximum noise levels observed here is significantly greater than those reported by Busch-Vishniac et al. (2005), and with multiple instances of peaks above 70 dB(A), even at night.

Table 4: Summary of results from the current study and comparison to previous studies

Study (Country)	**Locational setting**	**$(LA_{eq})_{mean}$**	**$(LAF_{min})_{mean}$**	**$(LAF_{max})_{mean}$**
Present (AUS)	Medical and surgical wards	54.8	43.7	71.3
Busch-Vishniac et al. (2005) (USA)	Medical and surgical units	52.1	46.9	62.7
Shield et al. (2016) (UK)	Medical and surgical wards in 2 hospitals	53.0	-	-

Noticeable LAF_{min} level decreases for around an 8 minute period at the beginning of the hour for much of the day were noted in the results for wards X1, X2, and X3, but not X4. Ward X4 is in a separate building to the other three wards. The spikes are thought to be attributed to an air-conditioning duty cycle, suggesting that for these wards, that the minimum noise level, especially at night, is primarily dictated by heating, ventilation, and air conditioning system noise. Such sudden sound power changes resulting from changes in operational mode and level of air-conditioning systems have been previously reported (Crocker et al., 2004).

5 CONCLUSIONS

A case study of sound levels in four wards was undertaken. Sound levels were measured in a number of locations including 4 and 6 bed multi-bed bays and nurse stations, for periods of up to 3 days. Maximum, minimum and average equivalent 1-minute A-weighted sound levels were seen to be relatively constant from 22:00 PM until 06:00, increase from 06:00 until 09:00, remain raised until 18:00, and then decrease from 18:00 until 22:00. Average noise levels as described by $(LA_{eq})_{mean}$ for nurses' bays and multi-bed patient rooms were found to be 56.6 dB(A) and 54.8 dB(A) respectively. Modest average noise levels increases were observed with increasing room/bay size with $(LA_{eq})_{mean}$ levels of 54.3 and 55.7 dB(A) for 4-bed bays and 6-bed bays respectively.

ETHICS

The local health network human research ethics committee and The University of Adelaide granted ethics approval.

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