Noise Pollution in the Hospital Environment of a Developing Country: A Case Study of Lahore (Pakistan)

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ABSTRACT

The present study investigates the noise pollution levels in public and private sector hospitals of Lahore. The noise pollution parameters were investigated from 20 public and 10 private hospitals. We observed that the Leq values varied significantly in different departments of the hospitals as well as at different times of the day. The public sector hospitals had significantly higher noise pollution compared to the private sector hospitals. The Wilcoxon Mann-Whitney two-sample rank-sum test revealed significant difference between noise levels in intensive care unit (ICU) during morning, and in emergency, waiting area, ICU, and reception during daytimes. However, no significant differences were found for any department during the evening. The Leqs

was found to be higher than the international norms (WHO standards) for all hospitals: higher than USEPA for 29 hospitals, and than local standards for 27 hospitals. Overall, significantly lower sound levels were always observed in private hospitals.

Keywords: Hospital noise; public sector; private sector; sound levels

Introduction

Noise is an unwanted sound whose detrimental effects have been widely observed in terms of auditory and/or non-auditory damages. It can cause annoyance, sleep disturbance, cardiovascular disease, and impairment of cognitive performance depending upon the noise exposure and personal degree of habituation.[1,2] Since most of the earlier studies have focused on occupational noise, there is need to examine its effects on a relatively sensitive community such as hospitals. In the hospitals environment, adequate comfort and sleep is vital for patient's recovery in most treatment regimens.[3,4] The staff conversations, delivery carts, ventilators, stretchers, medical emergency alarms, telephones, clinical monitors, creaking sounds of furniture and patients-attendants conversations are the major sources of noise pollution in hospital settings.[5-7] Previous studies have reported that the staff conversation was responsible for 56% of the hospital noise; whereas intensity greater than 65 dB(A) may decrease patients confidence in the clinical competency.[5] Moreover, in intensive care units (ICUs), even the sound of medical equipment's has been out-noised by avoidable background chatter of the attending staff.[8] The building design and acoustics may further affect the level of hospital noise. Several studies have reported high noise pollution in various hospital settings around the world.[4, 9-14]

In 1974, in order to address the significance of these health concerns, the United States Environmental Protection Agency (USEPA) devised standard values for hospital noise: 45 dB(A) during daytime and 35 dB(A) at night.[15] Afterwards, the initiative was step forwarded by World Health Organization (WHO), which proposed permissible limits for hospital noise ("*Guidelines for community noise*"): patient treatment areas (Leq $\leq$35 dB), night times

background noise (Leq ≤30 dB), and individual noise events (Leq ≤40 dB).[16]

However, in developing countries of South Asia, hospital noise pollution has not been given necessary attention. In Pakistan, ambient and traffic noise has been recognized through development of guidelines for permissible limits however, no emphasis has been given to the hospital noise. The present study was designed to characterize the problem of noise pollution in public and private sector hospitals in Lahore. We have also compared the levels of observed noise pollution with international and national standards for permissible limits; While the main focus was to establish the relationship between the noise exposure and the public/private status of the hospitals.

MATERIAL AND METHODS

Hospital Samples

Lahore is the second largest metropolitan of Pakistan with a population of ≈10 million and land area of 404 km^2. We surveyed 20 public sector and 10 private sector hospitals. Nearly all of the public sector hospitals were covered whereas, private sector hospitals were selected randomly (Table 1, Figure 1). The public and private hospitals are distinguished with different colors without assigning numbers as used in data to avoid political concerns.

Monitoring Program

The study was conducted from November 10, 2015 to December 12, 2015. The monitoring of noise in different areas of the hospitals was carried out using Lutron sound level meter, Model SL-4010 (Lutron Enterprise, Taiwan) with the measuring height fixed at 1.5 m above ground. The measurements were recorded as lowest (Lmin), maximum (Lmax) and Leq as noise parameters; it was found that even over short periods, these noises might have negative effects

on patients' health. The device was calibrated, as per the standard factory instructions; range: 40-130 dB, microphone — one electret condenser type with accuracy of ±2dB. The device was set to A-weighting for the measurement of noise level since it has been reported to be the most sensitive frequency for any sound level. The GPS coordinates of all the hospitals were also logged using GARMIN ETrax 20.

In each hospital, several locations were selected including reception, waiting area, emergency, ICU, and wardroom. Measurements were taken for one-hour sampling durations on daily basis. The sampling was performed at three time phases; in the Morning (08:00 am – 09:00 am) at Noon (12:00pm – 01:00 pm) and in the Evening (04:00 -05:00 pm). The sampling was conducted at 1-second constant intervals (i.e., slow response) throughout the sampling durations. An experienced audiologist, who was told to measure without alarming anyone and to prevent changing their routine habits, made the evaluations. The night hours were excluded from the study since the administration of most of the private and public sector hospitals did not allow for ethical restraints and sleep disturbance.

Statistical Analysis

Prior to applying the formal statistical test, boxplots were prepared to get general information about the overall distribution of the noise levels at different places in the hospital. The data for different locations in public and private hospitals was not following normal distribution, which was further confirmed by the `shapiro.test` in R statistical language. Therefore, nonparametric Kruskal-Wallis test (`kruskal.test`) was applied to identify significant differences among different places in the hospitals. Additionally, posthoc tests (`posthoc.kruskal.dunn.test`) were performed to identify the pair of places showing

significant differences using the well-known Bonferroni adjustment [17]. The comparison of noise levels at different places between public and private hospitals were drawn by considering a nonparametric Mann-Whitney U test using the `wilcox test` function in `R` statistical language [18,19].

RESULTS

The general presentation of noise level at different locations in the hospitals during morning, daytimes and evening hours is shown in Figure 2. It can be seen that the differences exist both within the same time period as well as across different time periods. Accordingly, noise levels comparison among public and private hospitals reflects similar findings (Figure 3-7).

Place Effect

The results of Kruskal-Walis test show the presence of place effect as at least one of the places has a significantly different noise levels as compared to other places (Table 2a). This is obvious from the low p-values of the test comparing Leq noise levels during morning, daytime and evening. Any probability value (*p*-value) less than 0.05 indicate a significant difference between comparative categories at 5% level. The Kruskal-Walis test did not provide any insight about the difference of noise pollution between places hence, the posthoc pairwise comparisons were made (Table 2b). The pairwise comparisons reveal that, during the daytime, pairs (E, ICU), (WA, ICU), (ICU, R) and (WR, R) were having significantly different noise levels (<0.05). Similarly, pair (ICU, R) is found to have significant differences for morning, and pairs (E, ICU) and (ICU, R) for evening time (cf. Table 2b).

Comparison of Noise Level in Public and Private Hospitals

The comparisons of noise levels among public and private hospitals were derived by using

Mann-Whitney U test {test statistic (*p*-value)} (Table 2). Moreover, it provides only those combinations where differences come out to be statistically significant at 5% level. The specific comparisons of the noise levels, at different places, and at different times in public and private hospitals, are described below.

Morning: Figure 3a shows the distribution of Leq in public and private hospitals with respect to different locations during morning time. Apparently, noise levels were higher in public hospitals, compared to the private hospitals, for almost all locations. Moreover, it can be observed that the average Leq noise level for public and private hospitals ranged from 63.6 to 69.9 dB(A) and 56.2 to 66.0 dB(A) respectively (Table 3). However, Mann-Whitney U test revealed that the Leq noise for emergency, ward, reception and waiting areas did not vary significantly; except ICU, at 5% level (*p*-value = 0.0278), and WA at 10% level (*p*-value = 0.0862) as shown in Table 2. Nevertheless, significant differences were observed at minimum noise level for emergency, waiting area, and ICU; while no differences were observed at maximum recorded intensity at any locality (Table 4).

Daytime: The average Leq measured during daytime ranged between 64.3 to 73.8 dB(A) in public hospitals was significantly higher than 57.3 to 66.6 dB(A) in private hospitals (Figure 3b; Table 3). Hereby, significant differences were observed among locations namely emergency, waiting area, ICU, and reception as shown in Table 2 & 3. Besides, minimum sound levels varied significantly for all locations whereas, maximum sound levels only differed at waiting area (Table 4).

Evening: The general comparison among average noise level of public and private hospitals is shown in Figure 4. Moreover, it can be seen that Leq during evening for public hospitals ranged

between 62.9 to 69.8 dB(A) for public hospitals and 56.9 to 66.9 dB(A) for private hospitals (Figure 3c; Table 4). The statistical comparison elucidated that no significant differences existed for Leq(s) and maximum sound levels at each location for both the public and private hospital; whereas minimum sound levels varied for emergency, ICU, wardroom, and reception (Table 4).

ICU Comparison and Compliance with International Norms

The distribution of the Leq noise levels in ICU for public and private hospitals with respect to each time of the day is shown in Figure 4. The chart reveals significant differences among noise levels in the ICU of public and private hospitals.

Besides, comparison of Leq in ICU with international norms illustrates that average sound levels measured in the both public and private hospitals were higher than the WHO (i.e., 35 dB during daytime). However, comparison with US-EPA standard (i.e., 45 dB during daytime) showed one private hospital was within the permissible limits of noise. Lastly, comparison with the standards devised by the government of Pakistan for ambient noise level in a silence zone, suggests that only 3 hospitals met the criteria of noise control, which were again private hospitals (Figure 5).

DISCUSSION

Noise control in the hospital setting is vital for patient satisfaction and improved health outcomes. During current investigation, we measured noise pollution in the hospitals' environment of Lahore, Pakistan. Each of the noise level recorded from all the public and private hospitals exceeded the permissible limits of 35 dB(A) as devised by WHO (1999). It has been previously reported that a normal healthy adult can bear about 50 to 55 dB(A) during the day and 40 to 45 dB(A) during night hours.[16] Although, the WHO recommended hospital noise levels are quite stringent; the levels were even higher than the USEPA standards, i.e., 45 dB(A), except for

one private hospital. During the daytime, the recommended limit is equivalent to a very quiet room and at night times, its well below normal conversation noise levels.[12] Nevertheless, Busch-Vishniac[20] suggested that, between 1960 to 2005, the hospital noise levels appeared to be increasing linearly by 0.38 dB/year and 0.42 dB/year during day and night hours, respectively.

The noise levels in public hospitals in any time of the day (morning, daytime, and evening) were higher than the respective timings in the private hospitals. The Leq values for these times are anyhow equivalent to those found in noisy large offices, i.e. 63 dB(A).[21] This can be associated to the (1) overcrowding of the public hospitals due to scarcity of affordable health care facilities, (2) lack of proper knowledge and training about the noise pollution, and (3) the locality of public hospitals in the areas with more population and health incidents. Pivatto and Gonçalves[22] have also reported higher noise levels (67.5 dB) in a public maternity hospital of Curitiba during the morning shift, and 65.3 dB in the visitation room during the afternoon. Similarly, Kakehashi et al.[23] recorded higher noise levels (61.3 to 66.6 dB) on weekend as compared to other days that can be attributed to the number of people visiting hospitals. The noise levels during night times, however, are not reported since the data collection was not possible due to the restrictions by the hospital management authorities. Moreover, since number of visitors/patients during night times are relatively less, and the relative incidents reporting is lower, the respective noise level could be ignored at this moment (hospital-management, personal communication, 2015).

On comparison of the current study with previously published studies from other parts of the world, it revealed that the Leq noise levels in ICUs were higher than those reported from Australia[4], Iran[11], United Kingdom[12] and were comparable with those reported from The

Netherlands[13] and Germany[24]. In general wards/rooms, the Leq noise levels in this study were greater than those reported from UK[9], Taiwan[10], and Tanzania[7] whereas, in emergency wards, it was greater than those reported from Iran[11]. However, in terms of overall hospital Leq noise levels, are greater than those reported from USA[14], lower than those reported from Iraq[25] and found almost consistent to those reported from India[26].

The higher noise levels may cause sleep disturbance, annoyance or other detrimental health impacts.[12] The sleep deprivation would be significantly linked with noise levels in hospital wardrooms.[27] The WHO recommends 35 dB(A) noise levels inside the hospital wardrooms to prevent sleep disturbance. In the recent years, a clear association between high hospital noise levels and poor health recovery due to sleep disturbance has been well-reported in number of studies.[27-30] Moreover, the high noise enhanced the production of angiotensin II in the blood, increasing the cholesterol levels, and the risk of strokes and diabetes[31], triggers high blood pressure, pulse rate, intracranial pressure, skin electrical resistance, sweating, contraction of peripheral blood vessels and hearing impairment.[27] In any case, often times, hospital noise can be reduced or eliminated by simple modifications to machine noises[32,33], through staff and attendants awareness and education[9,34] and maintenance of machinery and tools[35].The present study however suggests a timely need of noise regulation and policy instrumentation at national level.

CONCLUSIONS

It has been concluded that all the hospitals, regardless public sector or private sector hospitals, at all times of day, surpass the permissible international noise standards of 35 and 45 dB set by WHO, and USEPA, respectively. These values were even higher than the environmental

daytime noise limit of 50-dB requirement in Pakistan. Yet, in comparative terms, the public sector hospitals have higher noise levels than those in private sector hospitals. Therefore, the health ministry of Pakistan and hospital management should take initiatives and develop appropriate guidelines to mitigate this hazard. This will help improve the recovery of the patients and work efficiency of medicare staff. This is one of the preliminary studies from Pakistan to assess the hospital noise levels, there is an urgent need to conduct more studies on screening-level risk assessment, audiometric analysis, and sleep deprivation in patients from this part of the world. Moreover, necessary equipment's and standard procedures must be employed to reduce the noise level in the public hospital at foremost and private sections with more noisy areas.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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Table 1: Factors measured in the study.

Hospitals Inspected	Locations	Time	Sound Levels
Public (*n* = 20)	Emergency	Morning (8 – 9 am)	Minimum
Private (*n* = 10)	Waiting Area	Daytime (12 – 1 pm)	Maximum
Total – 30	ICU	Evening (4 – 5 pm)	Leq
	Ward Room		
	Reception		

Table 2: (a) Kruskal-Wallis test results, and (b) posthoc pairwise comparisons to identify significant differences in noise levels among different places in hospital

a. Kruskal-Walis test				
	Chi-square	df	p-value	
Morning Leq	13.147	4	0.011	
Daytime Leq	24.069	4	0.000	
Evening Leq	16.758	4	0.002	
b. Post Hoc Tests				
Morning				
	E	WA	ICU	WR
WA	1.000	-	-	-
ICU	0.144	0.801	-	-
WR	0.967	1.000	1.000	-
R	1.000	1.000	0.013	0.150
Daytime				
	E	WA	ICU	WR
WA	1.000	-	-	-
ICU	0.041	0.022	-	-
WR	0.557	0.356	1.000	-
R	1.000	1.000	0.000	0.008
Evening				
	E	WA	ICU	WR
WA	1.000	-	-	-
ICU	0.034	0.631	-	-
WR	1.000	1.000	1.000	-
R	1.000	0.545	0.002	0.188

The above results were obtained by applying `kruskal.test` and `posthoc.kruskal.dunn.test` in R statistical language

Table 3: Summary statistics and Mann-Whitney U test results for noise parameters in different times and places of the hospitals

		Emergency		Waiting Area		ICU		Ward Room		Reception	
		Mean	S.E	Mean	S.E	Mean	S.E	Mean	S.E	Mean	S.E
Leq	**Morning**										
	Private	65.25	0.33	62.84	0.57	56.21	1.01	61.57	0.79	66.01	0.65
	Public	68.58	0.29	67.25	0.33	63.68	0.4	64.81	0.3	69.92	0.31
	MW-U test	134 (0.143)		139.5 (0.086)		150.5 (0.028)		122 (0.350)		137 (0.109)	
	Daytime										
	Private	66.46	0.26	65.27	0.62	57.31	1.03	63.17	0.72	66.67	0.63
	Public	70.48	0.34	71.42	0.27	64.33	0.4	66.75	0.26	73.83	0.21
	MW-U test	148 (0.037)		152 (0.021)		146 (0.044)		126 (0.267)		169 (0.002)	
	Evening										
	Private	64.95	0.58	64.53	0.44	56.99	0.93	62.34	0.68	66.95	0.55
	Public	69.38	0.32	66.5	0.36	62.9	0.39	65.97	0.31	69.87	0.25
	MW-U test	141 (0.075)		120 (0.397)		135 (0.129)		134 (0.143)		141 (0.075)	
Minimum	**Morning**										
	Private	55.61	0.65	56.94	0.62	49.31	0.84	55.28	0.67	61.11	0.76
	Public	64.65	0.3	62.34	0.46	60.09	0.45	60.58	0.39	65.38	0.49
	MW-U test	170 (0.002)		147 (0.041)		163 (0.005)		144 (0.056)		142.5 (0.065)	
	Daytime										
	Private	58.94	0.48	60.07	0.74	50.63	0.87	57.29	0.55	61.48	0.72
	Public	65.12	0.44	67.11	0.37	59.04	0.47	63.26	0.31	70.39	0.24
	MW-U test	154.5 (0.018)		155.5 (0.016)		150 (0.029)		157 (0.013)		172 (0.000)	
	Evening										
	Private	57.83	0.66	59.07	0.64	49.59	0.78	54.23	0.89	59.65	0.82
	Public	65.14	0.37	61.17	0.49	58.54	0.46	62.73	0.39	65.86	0.33
	MW-U test	155 (0.016)		116.5 (0.481)		154.5 (0.018)		154 (0.019)		149 (0.033)	
Maximum	**Morning**										
	Private	74.89	0.52	68.73	0.74	63.11	1.26	67.86	1.04	70.91	0.61
	Public	72.5	0.34	72.17	0.32	67.28	0.39	69.05	0.31	74.47	0.26
	MW-U test	81 (0.416)		123 (0.328)		128.5 (0.218)		100 (1.000)		125 (0.281)	
	Daytime										
	Private	73.98	0.46	70.47	0.56	64	1.25	69.06	0.96	71.86	0.61
	Public	75.83	0.32	75.73	0.25	69.61	0.37	70.25	0.24	77.28	0.24
	MW-U test	123.5 (0.311)		150.5 (0.028)		137 (0.108)		107.5 (0.758)		154.5 (0.018)	
	Evening										
	Private	72.07	0.65	69.99	0.61	64.39	1.19	70.44	0.77	74.26	0.45
	Public	73.61	0.35	71.83	0.3	67.27	0.38	69.22	0.28	73.89	0.22
	MW-U test	114.5 (0.538)		122.5 (0.333)		125 (0.287)		91 (0.708)		100 (1.000)	

"In each block, first two rows represents mean and SE of the noise levels, whereas the 3rd row illustrates Mann-Whitney test statistic with p-values in parenthesis

Table 4: Locations with statistically significant differences at 5% level

		Morning	Day	Evening
MW-U test	Leq	ICU	E, WA, ICU, R	---
	Minimum	E, WA, ICU	E, WA, ICU, WR, R	E, ICU, WR, R
	Maximum	---	WA, R	---

[a]ICU = Intensive Care Unit

[b]E = Emergency

[c]WA = Waiting Area

[d]WR = Ward Room

[e]R = Reception

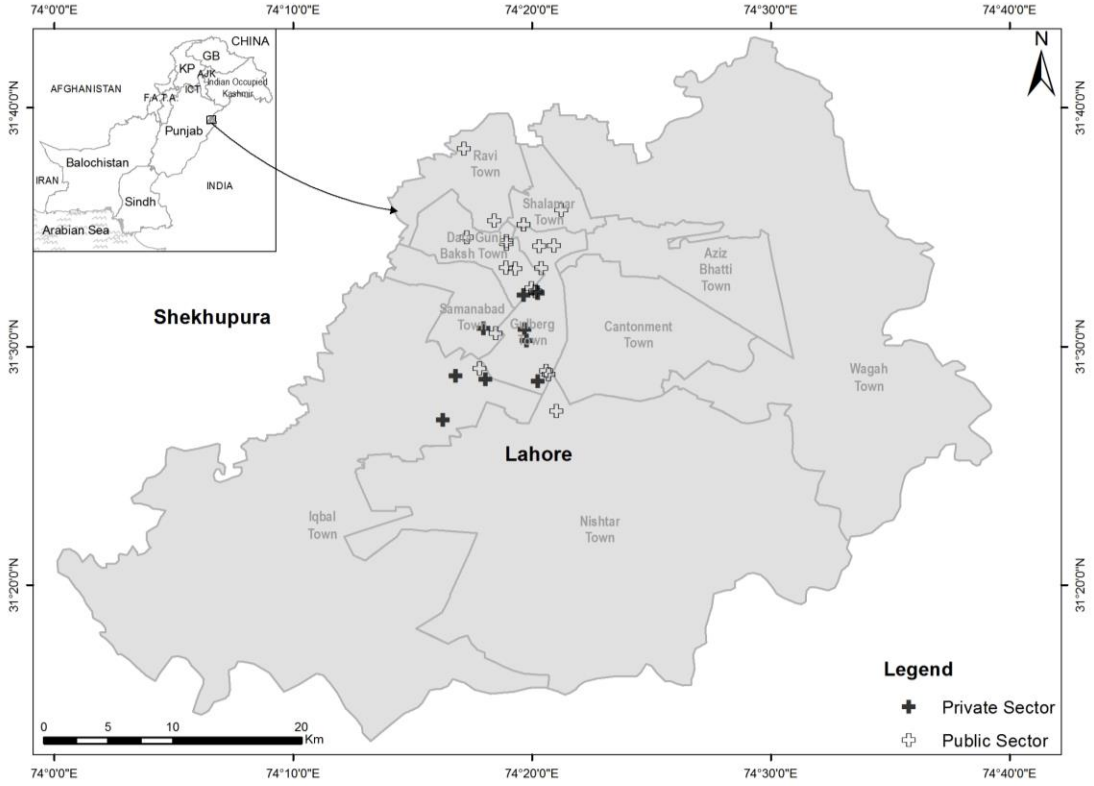

Figure 1: Study map showing public and private hospitals of Lahore (Pakistan)

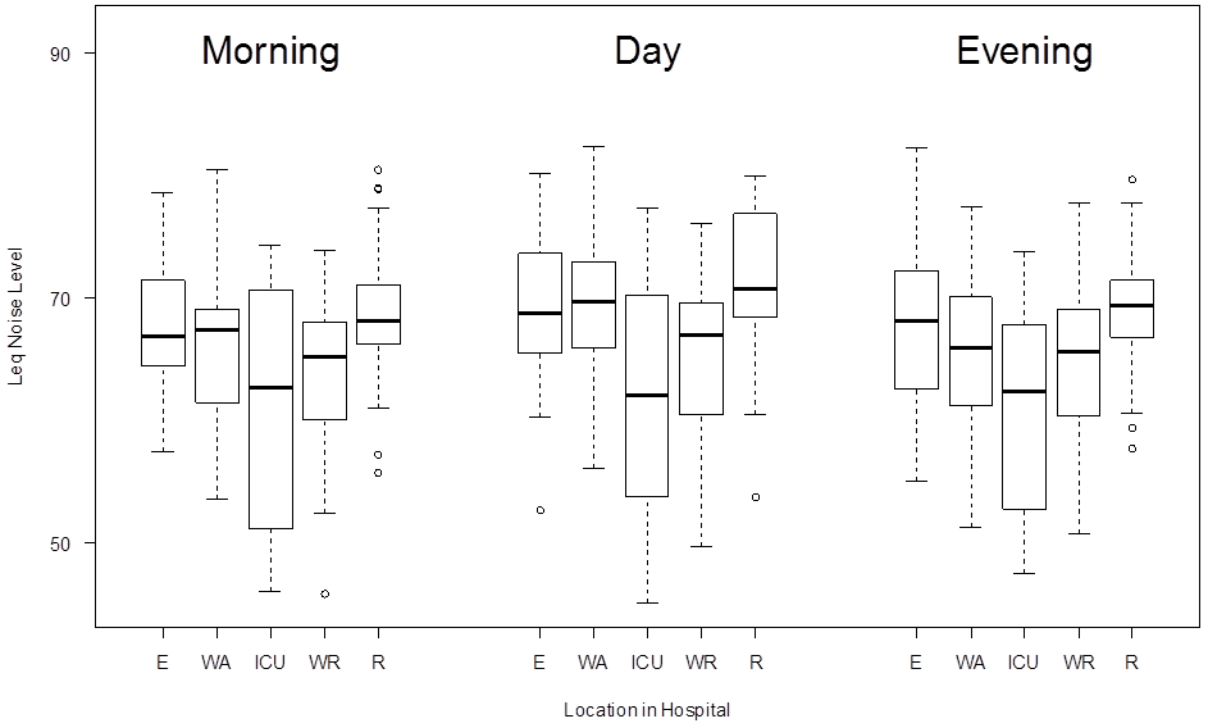

Figure 2: Distribution of the Leq noise levels in hospitals with respect to different locations during morning, day and evening time.

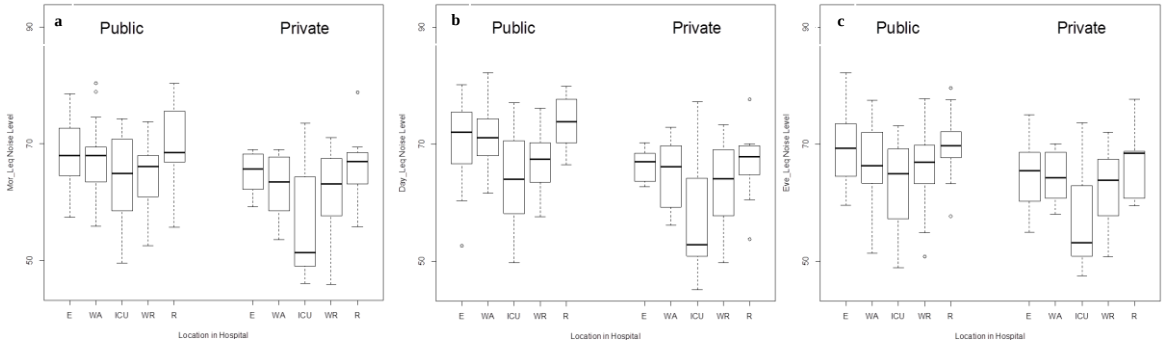

Figure 3: Distribution of the Leq noise levels in Public and private hospitals with respect to different locations during morning time (a), during daytime (b), and during evening time (c).

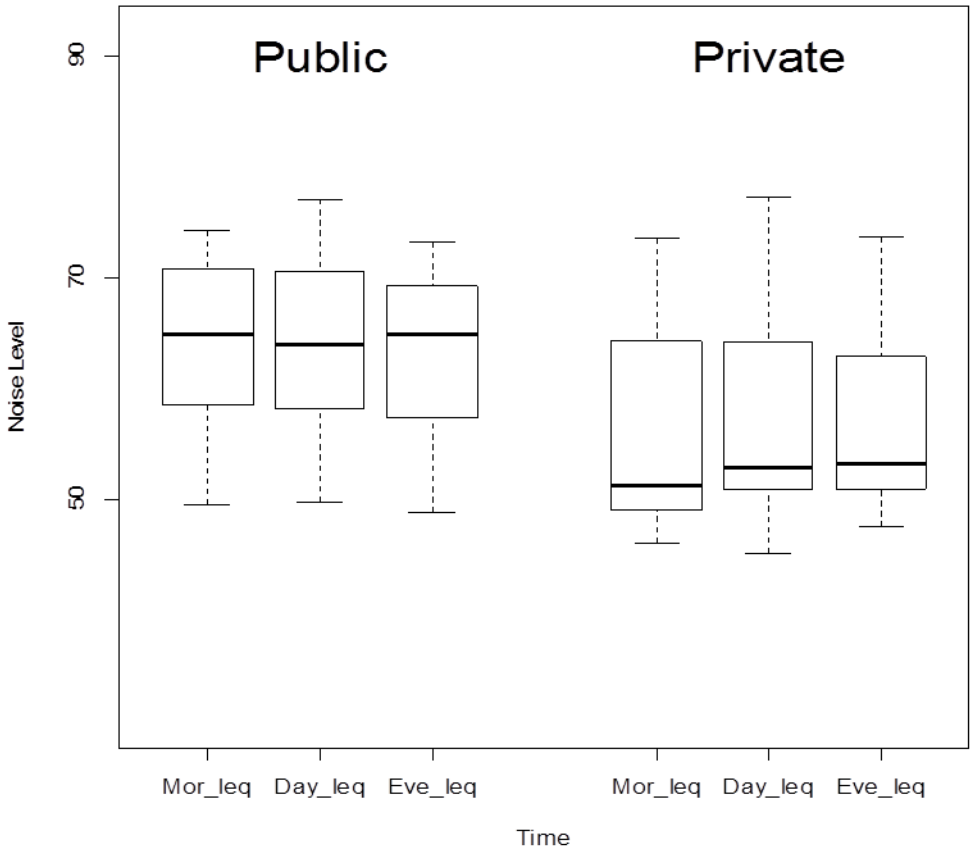

Figure 4: Distribution of the Leq noise levels in ICU for Public and private hospitals with respect to different times of the day.

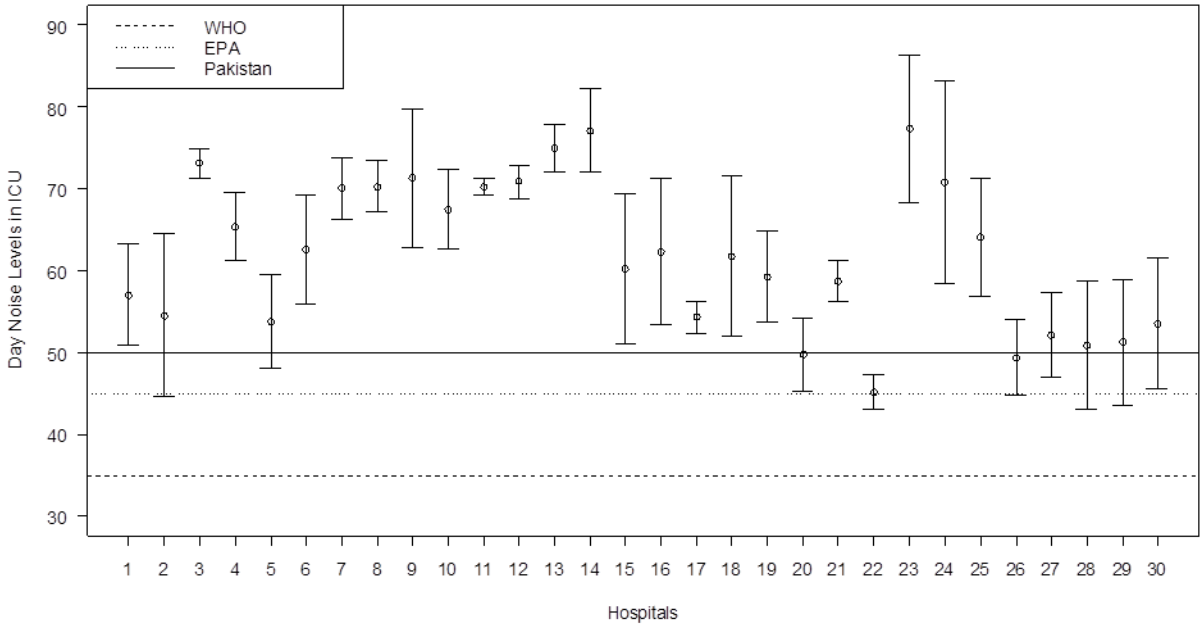

Figure 5. Noise levels in ICU for all hospitals during day time against the standards.