Original Article

The Evaluation of Noise Annoyance in a Tertiary Care Hospital

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Abstract

Aims: The aim of this study was the analysis of the relation between noise annoyance and the other sound indicators including speech interference level (SIL), preferred noise criterion (PNC), and sound pressure level (SPL) utilizing demographic variants (age, sex, marital status, and education) at the hospital. **Methods:** In this research, SPL was studied in the intensive care unit (ICU) and emergency department of Isfahan's Al-Zahra Hospital. Sound Level Meter (SLM) was undertaken according to ISO 9612 within the designated stations, followed by determining the SIL and PNC indicators. The questionnaire about noise annoyance and demographic variants was simultaneously filled out by 60 individuals. Eventually, the relationships between objective indicators with noise annoyance and also objective indicators with age variable were obtained by Pearson's correlation test, using SPSS version 16 and Excel software. **Results:** The results showed that the average indicators of SPL, PNC, and SIL with the values of 61.82, 51.03, and 70.79, respectively, were more than the respective standards. In addition, the results of analyzing noise annoyance showed that the mean and standard deviation of this parameter equals to 60.54 ± 1.43, which demonstrates the extreme rate of this scale. The Pearson's correlation test did not show any meaningful relation among noise annoyance and the indicators SPL, SIL, and PNC. However, a meaningful relation was found between the SIL and PNC indicators ($P < 0.005$). **Conclusions:** Considering the findings, an average of all acoustic indicators studied in the ICU and emergency departments of the hospital are more than the national standards. Furthermore, the scale of noise annoyance in the severe rating indicates that people in the hospital environment are affected by noise and are harassed. Based on this, it seems necessary to plan and adopt managerial and technical-engineering measures to reduce the level of noise pollution to the permitted limits of the standard.

Keywords: Noise pollution, noise annoyance, preferred noise criterion, speech interference level

Introduction

Despite the fact that sound waves are essential to human life and it is through them that communication with others is made possible or we are made aware of an incident, their intrusion in some cases and special situations is not pleasant.[1] The term "noise pollution" could be attributed to an intensity of sound that is able to disturb and negatively arouse people. This type of sound is uninvited and disconcerting, and lacks uniform rhythm.[2-8]

Hospitals are among the most important service environments in which high level of noise could have a significant effect on social well-being.[9] Technological innovations in hospitals increase noise pollution, which requires continuous assessment of patients in terms of patient and staff safety.[3,10]

Among the sources of noise pollution at hospitals, one could include the conversations between the medical staff, intercom devices within the building, overcrowded wards, moving metal devices, telephone ringing, computers and printers, and air-conditioning valves.[2,6,11-14] Other than these sources, Balog *et al*. stated that the highest level of noise at the intensive care unit (ICU) is created by mechanical alerts.[15] Faulk and Woods derived the same result from their study which proved the mechanical alerts to be capable of creating a noise from 48 dB up to 80 dB (A).[7]

To evaluate the field's sound, they use the speech interference level (SIL) and the preferred noise criterion (PNC) that SIL is used to demonstrate the rate of limitation or intrusion on verbal communication. Furthermore, PNC is a noise measurement

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Access this article online

Quick Response Code:

Website: https://journals.lww.com/IJEH

DOI: 10.4103/ijehe.ijehe_32_22

How to cite this article: Forouharmajd F, Saadatlo MA, Nakhaei Pour M, Pourabdian S, Asady H. The evaluation of noise annoyance in a tertiary care hospital. Int J Env Health Eng 2025;14:11.

Received: 15-08-2022, **Revised:** 30-07-2023, **Accepted:** 20-08-2023, **Published:** 23-05-2025

system for continuous or ambient noise in indoor environments proposed by Leo Beranek in 1971.[16]

Sound pressure level (SPL) is the result of the pressure variations in the air achieved by the sound waves. The elevation of SPL might cause stress, disorderly comprehension and interruptions in sleeping.[13,14,16-18] Sleep interruption could turn out to be provoking delirium in the ICU, in a way that between 30% and 75% of the patients are prone to experience at least a period of incomprehensible delirium while being hospitalized in the ICU.[19] The psychological effects caused by extreme noise level could result in behavioral perturbations and responses to anxiety.[11,14,16,18] Furthermore, noise could be a lethal cause of probable medical and nursing errors.[11]

Therefore, being checked into ICU is in conjunction with stressful environmental stimulants such as noise pollution, lighting problems, mobility limitations, and social isolation, among which noise pollution assumes a significant standing.[11,16] Dealing with noise is known as a mighty stress-inducing drive in ICU, but it is clear that annoyance caused by sound is an individual, subjective, and variable response.[17] Jalali *et al*. claimed that noise is the most important element in provoking pain in the hospitalization and postsurgical periods. Patients who experience noise will need a more dosage of sedatives than those away from noises.[8,20]

The results of the study in 2018 in one of the Zahedan hospitals showed that the SPL exceeded the recommendation of the World Health Organization (WHO) by an average of 50–65 decibels and also the level of SIL was obtained in the high and very high range, which shows the adverse sound condition of the hospital.[21]

The Environment Protection Agency has constructed certain guidelines, in which it recommends to prevent noise exceeding 45 dB during the day and 35 dB at night within the hospital rooms. The WHO suggests the individuals' conversations to be LAeq ≤40 dB.[10,18,19,22,23]

The existence of a calm atmosphere is one of the most necessary and vital points in the admission of patients to the hospital. Therefore, it is very necessary to know the level of noise intensity in hospitals compared to the recommended national standards. Since SIL and PNC indicators have not been investigated in previous studies, three effective parameters including SPL, SIL and PNC have been investigated in this research. Moreover, noise annoyance and demographic variables (age, gender, and marital status) were investigated in the largest educational and therapeutic hospital of Isfahan Province.

Materials and Methods

The present research took place cross-sectional in 2022 in order to describe and analyze effective parameters on the acoustic condition of Al-Zahra Public Hospital, which is a subset of the Isfahan University of Medical Sciences. Based on the previous study, 60 different individuals from various departments such as nurses, physicians, and patients, with ages of 20–50 years, 65% (39 people) females and 35% (21 people) males, were randomly selected and examined in the different work shifts.

Special care was taken in choosing the suitable location for the test, as it was located in those parts where people were not in hurry. Among the conditions of being included in the study were healthy state of hearing, willingness to participate in the project, and also not being exposed to sound intensity levels outside the hospital, all of which were determined in a face-to-face interview. Individuals with clear signs of exhaustion, those about to make phone calls, and those who had children were excluded from the study.

Measurement tools in this study were the sound level meter 801 which is designed by BSWA technology company in China, a tripod, sponge protector, demographic questionnaires, and Noise Annoyance Scale (NAS). Ultimately, the collected data were edited and analyzed using IBM SPSS Statistics for Windows, Version 28.0. (Armonk, NY: IBM Corp).

SLM test was undertaken in the permitted sections such as ICU and emergency. Room selection was randomly done, and all wards were divided into several stations through circumferential methods, allowing the test to be done in line with ISO 9612.[19,24] This standard was chosen because the direction and height of the microphone, along with the necessary time for measurement, are clearly defined, and more importantly, a precise protocol in all measurements has been designated.[24]

According to this standard, microphone height as the standing reception operator is 1.55 m, directed toward the sound source. In order to cancel the wind's effect, the microphone's receiver was covered with a sponge protector.[1,9,25,26] Using the SLM BSWA801, a positional SLM was done in three shifts of the morning (8:30–9:30), noon (11:30–12:30), and evening (4:00–5:00) and on the official weekdays (Saturday–Wednesday). Prior to the initiation of measurements and to verify the accuracy of the results, the audiometer was calibrated using a calibrator BSWA 801.[25] Considering the nature of services offered by nurses, and because they normally exposed to with various sounds, the equivalent sound level (Leq) was measured in the designated stations, for 30 minutes for the frequencies of one octave band and inA-weighted decibels. Subsequently, each section under scrutiny underwent comparison with the WHO standards and Iran's Department of Environment.[25]

In the next step, the sound analysis was performed in 'A' frequency weighting and the speech Interference Level (SIL) was calculated using equation 1, then compared with the relevant standards.

$$(SIL\,(dB) = \frac{SPL_{500} + SPL_{1000} + SPL_{2000}}{3}).^{[25,26]} \quad (1)$$

An SIL of above 0.75 dB is considered "good," 0.45–0.75 dB is "marginal," and lower than 0.45 dB is considered "intelligibility."[27]

In order to evaluate the confrontation rate of the staff and also the background noise, the PNC indicator was used and measured in such a way that the analysis of the sounds was put on charts, and the amount that was closest to the highest point in the chart was determined the PNC indicator. Later, it was compared with the numbers the PNC curve suggested for hospital sections, which was 25–40 dBA. The lowest curves are related to the sound levels appropriate for rest and good sleep, while the higher curves in a chart demonstrate a noisy space which delimits conversation and at times interrupts it.[16]

After 5 min, the NAS questionnaire was given to randomly selected people to determine mental parameters, and also the demographic variants such as age, sex, level of education, and marital status were collected using the questionnaire.[24] In order to establish the noise annoyance rate, individuals were asked to grade the surrounding noises and their annoyance from 0 to 100. The NAS was used for grading noise annoyance.[9] The general annoyance caused by noise is usually mapped out in a scale of 5–100. An annoyance of 5–10 is "low" and "medium" 20–50, while it is "high" when it reaches a number between 50 and 70, and "extremely high" when it reaches 70 and above.[9,24,25] The reliability coefficient of this questionnaire was obtained in the study of Golmohammadi 0.774.[26]

Statistical analysis

The Pearson's correlation coefficient test was used to investigate the relationship between objective indicators (SPL, SIL, and PNC) with noise annoyance and objective indicators with age variable and also to determine the relationship between PNC and SIL. Independent *t*-correlation test was used to determine the statistical relationship between subjective sound annoyance with the variable of gender and marriage, and one-way analysis of variance (ANOVA) was used to determine the statistical relationship between subjective sound annoyance and the variable of education level.

Results

Values of studied indicators

The individuals who filled out the noise annoyance questionnaires was 35% males, and 65% females, while 31.2 of them were single and 68.8 married. Twenty-seven of the subjects (44.3%) had bachelor's degree.

Positional SLM was undertaken in 202 stations in the emergency sections, ICU2, and ICU3 of the Public Hospital Al-Zahra. The results of calculating the average SPL in the aforementioned sections were, respectively, 66.63 ± 5.77, 59.06 ± 6.38, and 59.77 ± 6.59 dB, with the highest noise level being related to the emergency department of the hospital with 68.4 dB. The SPL in all the above sections exceeded national standards (45–55 dB).

SIL and PNC indicators were utilized in order to analyze the manner in which conversations are done. The results of calculating SIL in the emergency sections, ICU2, and ICU3 were, respectively, 78 ± 8.49, 66.25 ± 8.38, and 67.69 ± 8.57 dB, while the highest SIL (81.08 dB) was for the emergency department and the lowest (61 dB) for ICU2. Eventually, the resulting average for SIL was 70.79 dB which was labeled as "borderline" (45–75 dB).

The results of the PNC in the emergency sections, ICU2, and ICU3 were, respectively, 54.31 ± 5.47, 49 ± 6.08, and 49.78 ± 5.76 dB. The average PNC in the hospital exceeded the correlating standard (25–40 dB) in all the abovementioned measurements.

Investigating the relationship between the studied indicators

Statistical test showed that there is a meaningful relation between the indicators PNC and SIL ($P < 0.001$).

The average rate of noise annoyance is 60.54. Twenty-one percent of the noise annoyance was "medium," 49% was "high," and 30% was considered "extremely high."

The percentages of individuals with regard to the levels of noise annoyance are shown in Figure 1.

The results of the relationship between objective variables and noise annoyance demonstrated that there is no meaningful relation between the parameters of sound intensity level in emergency sections ($P = 0.811$), ICU2 ($P = 0.122$), and ICU3 ($P = 0.109$) and the indicators of noise annoyance. As shown in Table 1, Pearson's statistical test did not show a significant statistical relationship between sound annoyance and objective indicators ($P > 0.05$).

The results of *t*-test done to find the relation between sound mental annoyance and factors such as sex ($P = 0.359$) and marital status ($P = 0.958$) demonstrated that there is no meaningful statistical relation between these variants and mental annoyance. The results of one-way ANOVA in Table 2 showed that there is no meaningful relation existing between sound mental annoyance with level of education ($P = 0.820$).

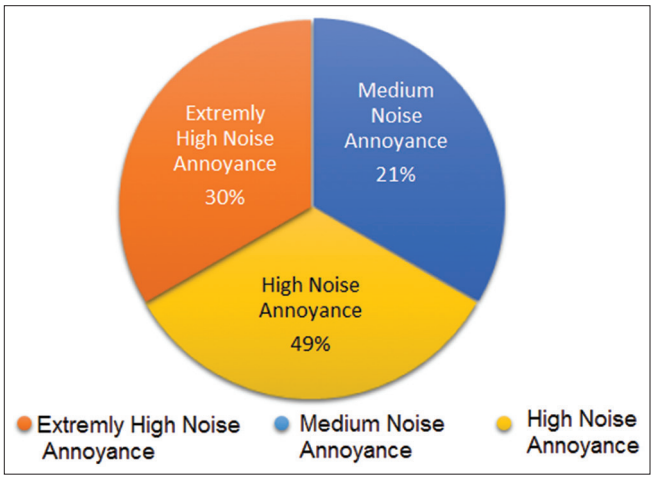

Figure 1: Levels of noise annoyance among the studied individuals

The independent *t*-test did not show a significant statistical relationship between objective indicators and age ($P > 0.05$) [Table 3].

The statistical test did not show a statistically significant relationship between SPL, gender, and marital status ($P > 0.05$) [Table 4].

Table 1: Relationship between speech interference level, preferred noise criterion, and sound pressure level with acoustic mental annoyance

Unit	SPL			SIL			PNC		
	Correlation coefficient	*n*	*P*	Correlation coefficient	*n*	*P*	Correlation coefficient	*n*	*P*
Emergency	−0.32	60	0.811	0.028	60	0.833	0.64	60	0.625
ICU2	−0.226	48	0.122	−0.149	48	0.312	−0.278	47	0.58
ICU3	−0.304	29	0.109	−0.381	29	0.41	−0.144	29	0.458

SPL: Sound pressure level, SIL: Speech interference level, PNC: Preferred noise criterion, ICU: Intensive care unit

Table 2: Relationship between demographic variants (sex and marital status) and mental noise annoyance

Parameters	Gender and marital status	Average	SD	95% CI		*P*
				Upper line	Lower limit	
Sex	Male	6.3	1.55	1.41	−0.42	0.363
	Female	6.66	1.37			
Marital	Single	6.53	1.71	0.778	−0.82	0.958
	Married	6.55	1.31			

SD: Standard deviation, CI: Confidence interval

Table 3: Relationship between objective parameters and the demographic variant "age"

Unit	SPL			SIL			PNC		
	Correlation coefficient	*n*	*P*	Correlation coefficient	*n*	*P*	Correlation coefficient	*n*	*P*
Emergency	−0.158	60	0.227	−0.99	60	0.45	−0.73	60	0.58
ICU2	0.458	48	0.001	0.521	48	0	0.461	47	0.001
ICU3	0.1	29	0.959	0.39	29	0.839	0.041	29	0.832

SPL: Sound pressure level, SIL: Speech interference level, PNC: Preferred noise criterion, ICU: Intensive care unit

Table 4: Relationship between sound pressure level and the variants marital status and sex

Units with objective parameters	Gender and marital status	Average	SD	95% CI		*P*
				Upper line	Lower limit	
SPL emergency	Sex					
	Male	66.68	6.44	2.66	−4.04	0.683
	Female	67.57	5.01			
	Marital					
	Single	66.01	4.72	1.83	−4.93	0.363
	Married	67.56	6.46			
SPL ICU2	Sex					
	Male	58.5	5.89	5.13	−2.33	0.454
	Female	59.9	6.4			
	Marital					
	Single	56.25	5.3	−1.08	−8.27	0.12
	Married	60.93	6.07			
SPL ICU3	Sex					
	Male	58.7	3.96	2.77	−4.91	0.574
	Female	57.64	5.55			
	Marital					
	Single	57.11	4.35	2.16	−5.46	0.383
	Married	58.76	5.28			

SPL: Sound pressure level, ICU: Intensive care unit, SD: Standard deviation, CI: Confidence interval

Table 5: Relationship between speech interference level and the variants marital status and sex

Units with objective parameters	Gender and marital status	Average	SD	95% CI		*P*
				Upper line	Lower limit	
SIL emergency	Sex					
	Male	80.26	7.05	2.87	−6.001	0.484
	Female	78.7	8.38			
	Marital					
	Single	77.13	7.44	2.22	−2.95	0.191
	Married	80.08	8.09			
SIL ICU2	Sex					
	Male	64.83	8.08	8.12	−1.99	0.23
	Female	67.9	8.62			
	Marital					
	Single	62.19	7.02	2.42	−6.83	0.007
	Married	69.03	8.3			
SIL ICU3	Sex					
	Male	65.79	4.64	4.85	−4.81	0.993
	Female	65.81	7.14			
	Marital					
	Single	65.2	6.09	2.34	−1.02	0.666
	Married	66.23	6.31			

SIL: Speech interference level, ICU: Intensive care unit, SD: Standard deviation, CI: Confidence interval

The statistical test did not show a statistically significant relationship between SIL, gender, and marital status ($P > 0.05$) [Table 5].

The statistical test in Table 6 did not show a statistically significant relationship between PNC, gender, and marital status ($P > 0.05$).

The statistical test did not show a statistically significant relationship between objective variants (SPL, SIL, and PNC) and the variant level of education ($P > 0.05$) [Table 7].

Discussions

Hospital is a substantial institution of medical and sanitary services that play a great role in retaining the individuals' physical and mental health, medical research, and education of the needed sanitary and medical workforce. Moreover, it tries to prioritize the comfort of the staff and patients in their period of hospitalization.

As it was discussed extensively in the results section, the average equal noise level within all three wards of the hospital exceeds the national standard. Excessive noise could easily affect overall health and could lead to the blurring of essential sounds.[17] Meanwhile, decrease in noise can bring about satisfaction, dwindling of anxiety level and the meticulous attention to professional duties, as well as boosting the nurses' performance.[2,16] A great number of studies in Iran and other countries are informants of noise pollution at various hospitals of big or small cities. According to the studies undertaken by Khademi *et al.* and Kooshanfar *et al*., the sound intensity level in ICU equals to 60 and 62 dB, which is similar to the average SPL of the present study, 61.82 dB.[8,28] Furthermore, in the study by Ivan Senis Cardoso Macedo in Brazil, the noise intensity level was 58.9 dB in the first ICU, and 64 dB in the second ICU, which are consistent with the present study's results.[14]

The present study's scope was not sufficient to evaluate the physical structure of the emergency department; however, sound emission through air conditioning systems, public addressing alarm systems, and the lack of noise absorbers are among the effective causes of increase in noise level in the emergency department.[11] Another factor in increasing noise level within this section was the proximity of hospital beds, where the lack of partitioning as well as the exposedness of the nursing station to all parts of the ICU attested to the inability to control noise levels.[7]

Bearing in mind the meaningful relation between PNC and SIL ($P < 0.001$), increase in background noise could cause lapses in verbal comprehension, which in turn can disrupt the patients' sleep and lead to consequences such as delirium.[2]

In a study done by Fasih-Ramandi and Nadri. in Iran's hospitals, the PNC and noise criterion (NC) curve for the equivalent sound level in 24 h was, respectively, more than PNC = 60 and NC = 55 dB, matching the average PNC which was calculated in this study.[16] Furthermore, noting the borderline status of SIL, in a space where the least level of background noise exceeds 45 to 50 dBA, people might need to increase their sound to 30 dBA, in a way that there occurs no difference between these two signals and comprehension could take place. This demands a high amount, as much as about 80 dB which could cause irritation, fatigue, and lapses in focus. This worrying condition could interrupt the professional undertaking of duties within the emergency section[13,18] increasing the risk of hindering cognition and response to

Table 6: Relationship between preferred noise criterion and the variants marital status and sex

Units with objective parameters	Gender and marital status	Average	SD	95% CI		*P*
				Upper line	Lower limit	
PNC emergency	Sex					
	Male	55.94	4.78	1.17	−4.62	0.238
	Female	54.21	5.4			
	Marital					
	Single	54.22	5.94	2.19	−3.74	0.602
	Married	55	4.96			
PNC ICU2	Sex					
	Male	48.27	6.01	5.2	−2.1	0.397
	Female	49.82	6.05			
	Marital					
	Single	46	4.25	−1.42	−8.38	0.007
	Married	50	6.17			
PNC ICU3	Sex					
	Male	50	3.97	2.55	−5.31	0.414
	Female	48.47	5.43			
	Marital					
	Single	48.66	5.08	3.07	−4.56	0.692
	Married	49.41	4.83			

PNC: Preferred noise criterion, ICU: Intensive care unit, SD: Standard deviation, CI: Confidence interval

Table 7: Relationship objective variants (sound pressure level, speech interference level, and preferred noise criterion) and the variant level of education

Demographic variable	Subjective and objective variables									
	Annoyance	SPL			SIL			PNC		
		ED	ICU2	ICU3	ED	ICU2	ICU3	ED	ICU2	ICU3
Level of education	0.82	0.703	0.423	0.765	0.892	0.115	0.814	0.346	0.058	0.89

SPL: Sound pressure level, SIL: Speech interference level, PNC: Preferred noise criterion, ICU: Intensive care unit, ED: Emergency department

alarms, which can have lethal consequences with regard to the patient's safety.[16,29]

Zamanian *et al*., in their study of analyzing the relation between noise annoyance with the overall health of the staff in the hospitals of the city Shiraz, indicated that there was a weak relation between noise annoyance and sound intensity level ($r = -0.017$) and not meaningful ($P = 0.885$), matching this study's results ($P = 0.122$).[9] In another study on noise pollution and the effects of noise annoyance, Golmohammadi *et al*. maintained that the intensity level of different wards' noises had no meaningful effect on the staff, statistically speaking ($P > 0.05$), matching the present study's results.[24]

From studies such as that of Golmohammadi *et al*., along with that of Hashemi *et al*., it could be derived that noise annoyance is rated higher in women than in men. Although it must be stated that in this study, there was no meaningful statistical difference between men and women regarding noise annoyance, the women's rate of noise annoyance has outgrown that of men, and this could have been caused by the high level of sound annoyance in Al-Zahra Hospital.[24,25]

Considering the age average of the individuals and also their grade of noise annoyance, it is possible that with the increase of individual's average age, noise annoyance is elevated as well, due to the fact that the elderly and the ill are potentially more sensitive to acoustic interruptions.[30,31]

In more sensitive wards such as critical care unit, the type of device alarms and recognizing them for a certain message and significance is of great importance. Thus, the personnel in this ward should constantly be prepared to be able to perform more responsibly, and this has made the staff in this ward more prone to being annoyed by unwanted noises.[25]

Conclusions

In this study, the SPL in all ICU sections exceeded foreign or national standards (Department of Environment) which informs us about its noise pollution. The noise in this place has a detrimental effect on health and disturbs the patients and the staff. Based on the achieved results, one concludes that the Al-Zahra Hospital in Isfahan has been made overly polluted with noise. The PNC and SIL indicators showed that conversations and dialogs in this hospital disrupt verbal communication and might lead to accidents. Thus, making

decisions to solve such problems and improving the acoustic condition of the hospital is of utmost importance.

Acknowledgments

We appreciate the efforts and cooperation of Isfahan University of Medical Sciences, Research Assistant, Managers, Nurses and Staff of Al-Zahra (S) Hospital.

Financial support and sponsorship

This article was based on a Master's Thesis, Research Grant: 399131.

Ethics code

This study was approved by the Research Ethics Committee of Isfahan University of Medical Sciences (code: IR.MUI.RESEARCH.REC.1399.215). All participants voluntarily participated in the study and provided written informed consent for participation. Confidentiality of the data was maintained.

Conflicts of interest

There are no conflicts of interest.

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