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Full Length Research Paper

Physiological effects of noise pollution on patients at Faisalabad institute of cardiology, Faisalabad and passive noise control measures

Muhammad Attique Khan Shahid*, Huma Bashir, Rukhsana Sabir and Mariam Saeed Awan

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The objective of this study was to evaluate noise pollution and its hazardous effects on patients' health recovery. Sound levels were measured in all wards of the hospital and changes in biomedical parameters were recorded and compared with standards because high levels of noise in hospitals may interfere with patient care services, doctor patient relationship and medical education activities. That is why more and more research is appearing to demonstrate the problem caused by noise which includes high blood pressure and increased pulse rate along with oxygen demand consequently increased and errors and staff attrition in hospitals and lack of speech privacy in professional offices suites. Noise pollution is also one of the risk factors for staff burn out and negative outcomes for the patients. This study is a humble attempt in this regard. The average, maximum average and minimum average noise level was found to be 71.80, 78.37 and 63.12 dB (A), respectively, in Surgical, Cardiology and ICU ward. The maximum and minimum values of systolic and diastolic blood pressures were 152.82/132.45 mmHg and 91.50/80.96 mmHg respectively. Similar trend was found to be in case of other biomedical parameters like pulse rate and oxygen demand and the results were confirmed through sociological survey. The observed noise levels in the Faisalabad Institute of Cardiology exceeded the recommended standards for hospitals and affected adversely the biomedical parameters of the patients hence delaying their recovery time.

Key words: Noise pattern, noise contributors, biomedical parameters, questionnaire analysis psychosomatic disorders, remedial measures.

Department of Physics, GC University, Faisalabad, Pakistan.

*Corresponding author. E-mail: profkhan786@yahoo.com, Tel: +92 302 6062879

INTRODUCTION

This study presents a comprehensive passive noise control program following the best practicable and economical options (BPEO) for implementations in different hospitals of Faisalabad for reducing annoyance and its ill effects on the patients, their relatives, medical and paramedical staff. It reviews potential application of noise control absorbers easily available in the market for the reduction of hospital noise and presents a simple solution as per requirement of technique for order of preference by similarity to an ideal solution approach (TOPSIS) for selection of appropriate sound absorbers on behalf of their absorption coefficient (Blomkvist et al., 2005; Black et al., 2012). Noise from different sources can cause annoyance, disturb sleep and effect health. Thus sound is potentially a serious pollutant and threat to environmental health.

The World Health Organization (WHO) classifies noise as the leading element of stressor that affects the well-being of the patients in hospitals. Environmental pollution is divided into different types like: air pollution, noise pollution, industrial pollution, etc. Among these, noise pollution will become the greatest evil for the human being especially for patients in the hospitals. Sound is a symbol of life and a fundamental means of communication among the human beings. But when it becomes un-wanted, undesired and irritate the listener it happened to be noise, and when it tempers the environment it becomes environmental pollution. It is a known fact from the relevant studies that noise pollution has been affecting the human health from the early days of industrial revolution. Noise of different intensity levels and harmony may affect our health positively as well as negatively (Busch-Vishniac et al., 2005; Black and Black, 2008).

Unnecessary sound in health care environment is the most cruel abuse of care that can be inflicted on either the sick or well equally. Studies revealed that high level of sound have negative physical and psychological effects, disrupting sleep, increasing stress and decreasing patient's confidence in the competence of their care givers (Black et al., 2007; Ryherd et al., 2008).

Hospitals are considered to be quite zones, like schools, to heal and get well. But Now a days the hospitals are noisy and the problem of noise pollution still exists even in new construction. The layers of sound proof and insulating materials are less thick in hospitals than in houses because of presence of bacteria in the hospitals. High noise levels in hospitals contribute to stress and lapses in hospital staff, reduced speed of patient's recovery, and there are evidences that hospital noise can negatively affect the communication and performance of the hospital staff (Castle et al., 2007; Manocha et al., 2009; Dlin et al., 1971). The situation has been worsening steadily. The World Health Organization has recommended different noise levels for day and night time that are commensurate with health promotion. In addition, there is remarkably little variation throughout the world for noise levels in different types of hospitals (Ryherd and Zimring, 2010a; Manocha et al., 2011). This suggests that the problem of hospital noise is universally threatening, and that noise control strategies and techniques should be adopted broadly.

There are many sources of noise in hospitals including air conditioning systems, medical devices such as respirators, and occupant sounds such as conversations impulsive noises, or very loud, short duration events are also common in hospitals. There are many other sources of noise which cannot be excluded like beeping, blaring, rattling, crashing noise that interrupt their sleep and they do not get proper rest to heal.

Intensive care unit or ICU is the major source of noise in hospital, because there are many types of equipment, essentials in order to alert physicians and nurses about changes in patient's conditions, and also malfunction of equipment (Manocha et al., 2012; Debono et al., 2012).

Since 1960, hospital noise level goes on increasing. These days, noise levels in hospitals have increased from 57 dB(A) in 1960 to 72 dB(A) during day time and from 42 dB(A) in 1960 to 60 dB(A) during night time (Debono et al., 2013). However, according to human hearing, a 10 dB(A) increase would seem to be as an approximate doubling of loudness (Jayasinghe et al., 2013). Accordingly, a 60 dB(A) sound seems to be four times as loud as a 40 dB(A) sound, despite having a pressure level 100 times higher. Further, many studies indicate that the highest noise level in hospitals is mostly greater than 85 dB(A) to 90 dB(A) (Aurell and Elmqvist, 1985; Marshall, 1972; Elmqvist, 1985; Aaron et al., 1996; Topf et al., 1996; Novaes et al., 1997; Kahn et al., 1998; Freedman et al., 1999; Walder et al., 2000; Freedman et al., 2001; Love, 2003; Hagerman et al., 2004; Blomkvist et al., 2005; Monsen and Edéll-Gustafsson, 2005). Noises from certain equipment that exceed 90 dB (A) (for example, portable X-ray machine) are same as walking next to a busy highway. Federal workplace safety standards mentioned 85 dB(A) as the limit of safe noise level for a whole shift without ear protection (National Institute for Occupational Safety and Health, 1998). Now a days it is an experimental fact that noise exposure is in fact a biological stressor which disturbs sensation of hearing psychologically and physiologically through human Ear, this disturbance then shifted to brain and affect the automatic nervous system by triggering a series of biomedical reactions, in glandular, cardiovascular, gastrointestinal and muscular systems interlinked with each other. The patients possess less ability to overcome stresses so affected adversely. Continuous noise may alter a patient's memory, increases anger and decrease patience.

This study was conducted to evaluate the noise level in different wards of the Rabia Trust Hospital, Faisalabad and to investigate the changes in some biomedical parameters such as noise level, heart pulse rate, blood pressure and oxygen concentration level of the patients from the selected observational site along with their impact on some selected parameters like, blood pressure, headache, sleep disturbance, stress, annoyance, depression and anxiety; using questionnaire method designed for that purpose and to find the co relationship between noise level and these biomedical parameters. Absorption coefficients of different absorbers having different thickness were also calculated and recommendations were made.

MATERIALS AND METHODS

Sixty (60) persons were randomly selected for this study, out of 60, 39(65%) were males and 21(35%) were females respectively, the information related to noise level measurements and biomedical parameters were thoroughly discussed with the ethical committee formulated for that purpose. The consent forms were filled by the sample patients along with fulfillment of other formalities as per requirement of WHO protocol and the study was conducted in a controlled and friendly environment. Data was collected from January 2011 to April 2012.

The following materials were used for the present study: A digital sound level meter model DT-8850 (having an accuracy of 1.4 dB), which can measure noise levels produced both near the source and the operator's level covering a range of 40-120 dB with a selectable A/flat frequency characteristic along with fast or slow time constants and impulsive response. Noise level measurements were taken on slow/response. A network was used in the present studies which approximate the human response. There is a similarity between the sound level meter and human ear in the way of responding to sound. In the sound level meter, the small signal sound is converted to identical electric signal by a high quality microphone. That signal is then amplified to be high enough to derive an ammeter. Since it is a precision instrument it has to be calibrated. Therefore provision was made to calibrate it for accurate results by placing a portable acoustic calibrator directly over the microphone.

A digital stop watch, 3 feet high iron stand, A meter rod, A digital blood pressure apparatus (BM-1004), A digital pulse oximeter or finger oximeter (CMS-50D) were used in this study. A questionnaire was designed to check the psychosocial effects of noise on patients. Different absorbing materials available in the market along with an audio generator and wooden box with a hole in one wall to insert the absorbers were also employed for this study (details are available in the relevant table). The acoustic ABC principles “absorb”, “block”, “cover” are a useful way to consider reducing noise pollution in the hospitals. Isolated box system has three in one qualities on behalf of which it was used in this study. To reduce the noise level up to optimum level a specially designed isolated box with dimensions 4'x8' sheet of 1' or thicker particle board, building a box within a box with sound isolation foam in between. The outer box is about 4'x4'x8' (beware of symmetry resonance) double layer window to see inner view. Light arrangements were provided inside cable insertion and absorber's fitting portion to see proper arrangements; calibrated rod was available for position adjustment; entire box with 3" foam sheet for sound reduction with 6" of toe space at its front arrangement was designed for this study and was used for data acquisition because such arrangements were used in most of the hospitals throughout the world for extra noise absorption. The room was devised in a special manner to allow only human noise filtering or absorbing all other unwanted sounds having frequencies outside the human audible frequency range.

Noise levels were measured from 8:00 am to 20:00 pm during January, 2011 to April, 2012, at the various selected sites in Surgical, Medical, Oncology, Pediatric, Urology and Orthopedic wards of the Faisalabad institute of cardiology, Faisalabad, Pakistan. The readings were taken after every 2 h. All measurements were made on weighting scale and sound level meter was switched to slow response position. Readings from sound level meter were taken in every first 5 min of an hour. Noise level meter was placed at a height of 3 feet from the ground on an iron stand. All observations were made at center of the ward. The number of patients admitted in different wards of the hospital was also measured. Average noise level for 5 min was calculated using the formula:

$$L_{eq} = 20 \log (1/N) \sum 10^{L_j/20} \qquad (1)$$

Where N is the number of observations and L_j is the jth noise level.

The biomedical parameters such as blood pressure, pulse rate and blood oxygen concentration were also measured. Two or three readings were taken each about 2 min apart and then the average was worked out (only whole numbers were taken and decimals were rounded off). The oxygen concentration in the blood for each patient was measured using a digital pulse oximeter. The data was analyzed statistically using SPSS analysis and computer excel program. Analysis of variance (ANOVA) test was used to detect the effects of sound pressure level on both blood pressure and heart pulse rate; obvious influence of sound level on blood pressure as well as heart pulse rate was observed for that purpose and multiple compositions were carried out. Pearson’s coefficient was used to check the strength of the data. The patients were personally interviewed by the scholar keeping in view the cross section of different groups, sex, age, geography, educational level and income status, etc. on behalf of whom they can be treated as true representative for such type of studies. For health hazards analysis, the work sheets were prepared for all types of effects following the WHO criteria and significant and non-significant data was worked out. The obtained data was analyzed and was interpreted under the guidance of ENT specialist and psychiatrist of DHQ Faisalabad.

Different absorbing materials, available in the local market, were also tested using a high frequency audio generator in order to check their absorbing capacity using the idea of absorption coefficient as a passive noise control technique. Absorption coefficients recommended to control noise pollution in hospitals were also calculated and found to be correct as per standard given in the literature (Kryter, 1985; Hansen, 2005; Everest, 2001; Berglund et al., 1999). Audio frequency generator was inserted into a wooden box with hole in one wall and high frequency sound was adjusted as per standard found in the literature and its sound level was measured using sound level meter and was calibrated accordingly. Different absorbing materials were inserted into the box one by one and sound level was measured for each and the change in sound level was worked out. The absorption coefficients were calculated for each absorbing material and compared with the standard values given in the literature. The diagrammatical sketch of the closed box system is shown in Figure 1.

RESULTS

Total number of beds in different wards of Faisalabad Institute of Cardiology Faisalabad was 200. The numbers of beds in each ward were 20, 15, 20, 20, 5 and 20 in Emergency, Surgical, and CCU1, CCU2, ICU, and

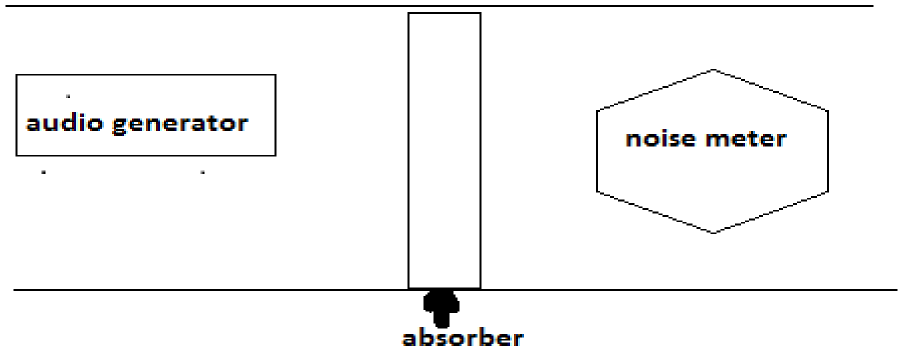

Figure 1. Schematic diagram of isolated box method.

Table 1. Average noise levels in different wards of Faisalabad Institute of Cardiology, Faisalabad, Pakistan.

Time	Emergency	CCU 1	CCU 2	Cardiology	Surgical	ICU	Average Noise level (dB(A))
8:00	62.152	69.15	66.075	67.35	52.255	61.757	63.123167
9:00	64.725	69.905	67.05	66.925	60.59227	62.75	65.324545
10:00	66.35	70.955	68.425	69.475	60.225	63.45	66.48
11:00	67.455	71.372	69.3	70.45	65.3699	65.465	68.235317
12:00	68.18	72.89	71.975	71.325	67.875	67.125	69.895
13:00	72.299	74.23	71.225	72.6375	69.9375	68.455	71.464
14:00	76.25	75.4325	72.325	73.675	74.375	69.108	73.527583
15:00	75.38	75.64	75.175	74.375	74.3699	70.925	74.310817
16:00	74.2938	76.37	76.525	70.3625	69.14	68.125	72.469383
17:00	78.575	80.82	80.725	76.125	73.5714	72.375	77.0319
18:00	75.782	79.64	79.15	76.255	71.125	71.12	75.512
19:00	79.125	81.875	80.45	78.725	74.586	75.512	78.378833
20:00	78.21	81.425	79.675	79.525	72.709	74.443	77.6645
Average noise level	72.2136	75.3618846	73.69807692	72.861923	68.16392077	68.508462	71.801311

cardiology wards respectively. The result of the analysis of noise levels, bio medical parameters, psychosocial effects, along with absorption coefficients of absorbers using isolated box system in Faisalabad Institute of Cardiology I are shown in Tables 1-5 and Figure 1 respectively. The maximum average noise level was measured in Cardiology ward (78.37 dB (A)) while the minimum average noise level was measured in ICU ward (63.12 dB (A)). The Cardiology, CCU1 and CCU2 wards were found to be at risk because the values of noise levels exceeded the WHO standards. The average value of noise level in Faisalabad Institute of Cardiology was 71.80 dB(A). The noise level of CCU1 ward was found to be maximum (81.87 dB(A)). The noise pattern followed by the Faisalabad Institute of Cardiology wards was CCU1 > CCU2 > Cardiology > emergency > ICU > surgical respectively. Biomedical parameters like systolic and diastolic blood pressure, heart pulse rate, and oxygen saturation were also measured and their average values are shown in Table 2.

It was concluded from Table 2 that the maximum average value of systolic blood pressure was found (152.81 mmHg). Minimum average systolic blood pressure was found (132.45 mmHg). The maximum average value of diastolic blood pressure in Faisalabad Institute of Cardiology, Faisalabad, was found to be 91.50 mmHg and minimum average value was found to be 80.96 mmHg. The average value of systolic blood pressure as measured in the Faisalabad Institute of Cardiology 141.94 mmHg while average diastolic blood pressure was found to be 87.44 mmHg. Average heart pulse rate found in Faisalabad Institute of Cardiology was 85.47 beats per min. The number of patients who had heart pulse rate greater than the normal value of HPR was 79 of which 36 were male patients and 43 were female patients. The maximum average heart pulse rate

Table 2. Average values of biomedical parameters in Faisalabad Institute of Cardiology, Faisalabad, Pakistan.

Average Noise level	Average systolic blood pressure	Average diastolic blood pressure	Average heart pulse rate	Average SpO_2 concentration
63.123167	129.7555	80.96357	80.75983	93.775
65.324545	132.4503	82.19847	82.19777	95.975
66.48	135.5928	84.47553	83.69638	98.0025
68.235317	138.1094	85.91341	84.82252	98.9
69.895	141.4605	87.80284	86.61107	99.5
71.464	144.5661	89.37228	88.02112	100.45
73.527583	147.7623	91.50425	89.01199	99.675
74.310817	149.1687	91.68859	88.86524	98.2
72.469383	148.4128	91.42226	88.4204	95.375
77.0319	146.5783	89.92023	86.84595	92.375
75.512	152.8135	88.34038	85.51197	90.4
78.378833	140.5036	87.29337	83.90107	87.9
77.6645	138.149	85.9323	82.49293	86.1

Table 3. Psychosocial effects of noise pollution on human health.

Psychosocial effets of noise pollution	Percentage of effectees
Annoyance	7.14
B.P.	14.29
Headache	14.29
Sleep disturbance	24.28
Stress	22.86
Anxiety	14.29
Depression	2.85

Table 4. Absorption coefficients of absorbers using isolated box system.

Name of material	Sound level (dB)	Thickness of material (mm)	Absorption coefficient $\mu = \frac{(L_o - L)}{10x}$	Standard absorption coefficient μ_0 $(mm)^{-1}$	Difference $\mu_0 - \mu$
Polystyrene	81.8	22.69	0.036	0.03	-0.006
hard board sheet	77.8	4.49	0.27	0.3	0.03
Chip board	75	7.17	0.209	0.2-0.3	0.041
Formica	74	0.93	1.72	N.A.	N.A.
Plaster of Paris sheet	88	10.46	0.0191	0.07-0.6	0.3159
Woolen cloth	75	0.99	1.515	1.03	-0.485
Cotton cloth	90	0.87	0	N.A.	N.A.
Rubber sheet	73.9	1.9	0.847	0.4-0.8	-0.247
Tile	76.7	7.07	0.1881	0.1-0.2	-0.0381
Carpet	72.7	7.37	0.2347	0.65	0.4553

Max. Sound level measured in hospitals = 90 dB(A). Frequency of sound level at 90 dB(A) = 40,000Hz. (Calibration used in this study) L_o = 90dB(A).

() in Faisalabad Institute of Cardiology is 89.01 beats per min. The oxygen saturation level was also checked in the patients of Faisalabad Institute of Cardiology, where the average value of oxygen concentration was 95.12% (Toivanen et al., 1960; Gardner et al., 1960; Minkley, 1968; Falk and Woods, 1973; Hilton, 1976; Cantrell, 1979; Cohen, 1979; Sonnenberg et al., 1984; Baker, 1984; Norbeck, 1985; McCarthy et al., 1992; Baker,

Table 5. Absorption coefficients/Categories recommended for specially selected sites.

Name of material	Sound level (dB)	Thickness of material (mm)	Absorption coefficient $\mu = \frac{(L_o - L)}{10x}$	Standard absorption coefficient $(mm)^{-1}$ μ_0	Difference (μ_0-μ)/ Noise reduction %age	Recommended sites
Formica (A)	74	0.93	1.72	N.A.	(0.00)/100%	Furniture items, patient's beds and walls and roofs of the wards
Woolen cloth (B)	75	0.99	1.515	1.03	(-0.485)/53%	Medical and paramedical staff along with Patients should make pure woolen or woolen mix cloths as a compulsory part of dress
Carpet (C)	72.7	7.37	0.2347	0.65	(0.455)/30%	Pieces of carpets for in between heavy machinery parts and the parts of patient's bed along with floor

1992; Baker et al., 1993; Topf and Davis, 1993; Wysocki, 1996; Carley et al., 1997; Berg, 2001; Parthasarthy and Tobin, 2004; Castle et al., 2007).

The questionnaire analysis was made to point out the percentage of effects of different disturbances which were 20.73, 17.9, 16.7, 16.7, 11.7, 10.9 and 6.2% for blood pressure, headache, sleep disturbance, stress, annoyance, depression and anxiety likewise as depicted in Table 3 with p value equal to 0.520.ref. The absorption coefficient of different absorbers available in the market, of varying thickness, were calculated using Beer-Lambert's law and compared with the standard values of absorption coefficients found in the literature. Luckily, the values of absorption coefficients for most of the materials were found to agree with the standard values. Three materials Formica, woolen clothes and Carpets having absorption coefficients (μ); $1.7m^{-1}$ (A), $1.5m^{-1}$ (B) and $0.8m^{-1}$ (C) respectively were used and hence were recommended as an ideal noise absorbers within the hospital environment. The porous absorbers were used due to their high quality sound absorption. When the sound wave strikes on the porous absorber, the absorber material sit into vibrations being resisted by viscous forces near the surfaces of the fibers, resulting in the transformation of the sound energy in heat depending upon the porosity of the material. The maximum absorption will occur when the thickness of the absorber equals on fourth of the wavelength not the incident sound, the attempt has been made to fulfill this condition during this study; furthermore, the absorbers were covered with thin plastic sheet not only to prevent them from contamination and spilling but also to enhance the absorption coefficient. The details for using these materials as noise absorbers are given in the Tables 4 and 5.

DISCUSSION

The maximum average noise level was measured in Cardiology ward (78.37 dB(A)) while the minimum average noise level was measured in ICU ward (63.12 dB(A)). The Cardiology, CCU1 and CCU2 wards were found to be at risk because the values of noise levels exceeded the WHO standards. The average value of noise level in Faisalabad Institute of Cardiology was 71.80 dB(A). The noise level of CCU1 ward was found to be maximum (81.87 dB(A)). The noise pattern followed by the Faisalabad Institute of Cardiology wards was CCU1 > CCU2 > Cardiology > emergency > ICU > surgical respectively, and ASBP>AOC> ADBP >HPR respectively, while for health hazards it was sleep disturbance > General stress >headache B.P.> annoyance > depression> respectively, as depicted in Figure 3 with p value equal to 0.6952. Parthasarthy and Tobin (2004) and Castle et al. (2007) states that noise level has very strong positive co–relationship with biomedical parameters, but very weak positive co–relationship with psychological and physiological effects.

But the conclusions drawn by the authors are limited due to limited subject population, lack of acoustic knowledge, controversies in the literature, and limited research work on the subject. The important contributors to noise level in the wards were conversations among patients and Para-medical staff, overcrowding of patients relatives, medical and power supply instruments, especially, generators during load shedding hours and screaming of children. However, noise pollution was not only the main cause of such disturbance but air pollution, water pollution, etc. were also contributing a lot. Hence, need of noise monitoring for an optimal hospital environment along with its negative impact on the quality of the health care practices and the performance of the staff (both medical and Para medical) is strongly recommended. For comprehensive study more research is needed (Ryherd and Zimring, 2010b). The future work should include measuring HPR, DBP, SBP, first in control environment for several hours and then repeated in hospital environment keeping in view the standards of SPL.

Long term and short term noise effects on patient's health were observed in different wards of the hospital; on behalf of these observations some precautions have to be considered to reduce the noise effect. As a result of this study, the following recommendations are suggested to improve the hospital environment (Dialogues).

There must be a specific goal oriented research for identification. The ways to improve acoustic environment, like room shape, equipment installation at proper places, use of absorbers at specially recommended sites, strides can be made in filling the holes in the research chain and providing a healthier atmosphere for the patients, staff and visitors. Combined administrative and designed strategies are needed to combat the issue like behavioral changes, silence zones, modification in sound systems, modification in architectural design and rigorous use of porous absorbing materials, because such effects have shown the results in reducing noise level and shortening in patients recovery time.

Conclusion and Recommendation

Noise pollution in hospitals has been a serious issue and is linked with a spectrum of negative impacts on the recovery of patients. The porous absorbers were used due to their high quality sound absorption. When the sound wave strikes on the porous absorber, the absorber material sit into vibrations being resisted by viscous forces near the surfaces of the fibers resulting in the transformation of the sound energy in heat, depending upon the porosity of the material. The maximum absorption will occur when the thickness of the absorber equals on fourth of the wavelength of the incident sound; the attempt has been made to fulfill this condition during this study. Furthermore, the absorbers were covered with thin plastic sheet, not only to prevent them from contamination and spilling, but also to enhance the absorption coefficient. The actual cause is still unknown but some hypothesis based information is available in literature. Sleeping plays key role in recovery of patient's health. Alertness, mood, behavior, coping abilities, respiratory muscle function, ventilatory control, healing time and duration of stay in the hospital are the few factors responsible for sleep disturbance or deprivation. Stress exhausts the biological resources available to combat the diseases and enhances the patient's recovery time. From this study, it was concluded that using sound proof materials and absorbents while constructing buildings of hospitals for different wards for example, using fiber glass has shown good insulation as compared with gypsum. It was also observed that if these absorbers were mixed into a one package, their absorption coefficient will become 1.03 times more efficient; therefore, it will be possible to formulate a tool kit capable to achieve zero (background) noise level; not only for buildings, but also for other infrastructure used in the rooms.

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