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Assessment of noise pollution in and around a sensitive zone in North India and its non-auditory impacts

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HIGHLIGHTS

- Studied noise pollution and its non-auditory health impacts around a sensitive site
- All sites have higher L_{eq} than the permissible limit, during day and night hours
- Highest SPL was recorded in ambulance vans (87-104 dB), which carries the patient
- 74% respondents reported irritation, whereas 40.4% suffered noise induced headache
- There is need to reduce noise through awareness, hospital engineering & acoustic measures

GRAPHICAL ABSTRACT

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ABSTRACT

Noise pollution in hospitals is recognized as a serious health hazard. Considering this, the current study aimed to map the noise pollution levels and to explore the self reported non-auditory effects of noise in a tertiary medical institute. The study was conducted in an 1800-bedded tertiary hospital where 27 sites (outdoor, indoor, road side and residential areas) were monitored for exposure to noise using Sound Level Meter for 24 h. A detailed noise survey was also conducted around the sampling sites using a structured questionnaire to understand the opinion of the public regarding the impact of noise on their daily lives. The equivalent sound pressure level (L_{eq}) was found higher than the permissible limits at all the sites both during daytime and night. The maximum equivalent sound pressure level (L_{max}) during the day was observed higher (>80 dB) at the emergency and around the main entrance of the hospital campus. Almost all the respondents (97%) regarded traffic as the major source of noise. About three-fourths (74%) reported irritation with loud noise whereas 40% of respondents reported headache due to noise. Less than one-third of respondents (29%) reported loss of sleep due to noise and 8% reported

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hypertension, which could be related to the disturbance caused due to noise. Noise levels in and around the hospital was well above the permissible standards. The recent Global Burden of Disease highlights the increasing risk of non communicable diseases. The non-auditory effects studied in the current work add to the risk factors associated with non communicable diseases. Hence, there is need to address the issue of noise pollution and associated health risks specially for vulnerable population.

1. Introduction

According to Florence Nightingale "Unnecessary noise is the most cruel abuse of care which can be inflicted on either the sick or the well" (Nightingale, 1992). Noise pollution in hospitals can impact sleep cycle, cardiovascular response, pain management, wound healing and other responses in a patient (Baker et al., 1993; Cohen, 1979; McCarthy et al., 1992; Sonnenberg et al., 1984; Stanchina et al., 2005; Topf and Davis, 1993; Topf et al., 1996; Wysocki, 1996). Cmiel et al. (2004) reported noise as a primary cause of sleep deprivation. Noise levels have also been shown to alter staff stress level, impact job performance, induce hearing loss at high noise levels, create annoyance and cause an increased rate of burnout (Bayo et al., 1995; Blomkvist et al., 2005; Love, 2003; Morrison et al., 2003; Norbeck, 1985; Zhang et al., 2012). Thus, noise pollution in hospitals is recognized as a serious health hazard and not just a nuisance.

World Health Organization (WHO) recommends continuous background noise in hospital rooms to be <35dB, with nighttime peaks in wards not to exceed 40 dB (Berglund et al., 1999). Although previous studies have reported high noise levels in hospital settings far exceeding permissible limits, little attention has been paid towards mitigating the hazards of noise pollution in hospitals. The objective of this study was thus to map the levels of noise pollution and explore the non-auditory effects of noise in a tertiary medical care institute in North India and thereby suggest measures to reduce noise and associated health impacts.

2. Methods

The study was conducted as per the guidelines of International Commission on the Biological Effects of Noise (ICBEN) for investigating noise levels, community response and its effects on the community. The study was conducted in an 1800-bedded tertiary hospital with a bed occupancy rate of 95% and more than 20 lakh outpatients annually. A total of 27 sites, outdoor, indoor, road side and residential areas were monitored for exposure to sound using Sound Level Meter (SLM). Envirotech (New Delhi) make Sound Level Meter (SLM100) was used in the current study considering its ease in field operations.

The SLM100 is a "Type 2" Integrating Sound Level Meter, which measure noise levels as dB(A). SLM was installed above 1.2 m using a tripod. Each location was monitored for 24 h including both day and night observations. The duration from 6 am to 10 pm was considered daytime whereas the time period from 10 pm to 6 am was referred as night time as per "The Noise Pollution (Regulation and Control) Rules, 2000". Sound level, diurnal pattern and weekend vs. weekday trend were also investigated. The indoor micro-environmental locations included emergency, intensive care unit (ICU), Trauma centre, library and other hospital buildings. The outdoor locations were parking areas, parks, shopping complexes, entrance gates etc., whereas the residential area included Doctor's Hostels and Staff quarters. Before visiting a location, the facility/location in-charge was informed about the purpose of the study and informed consent was taken before actually carrying out noise monitoring and the survey.

ICBEN questionnaire was adopted to conduct a detailed noise survey around the sampling site to know the perception of the exposed individuals (medical professionals, nurses, residents, patients, visitors, employees and other people in and around the institute campus) regarding the effect of noise in their daily life. Taking the prevalence of irritation/annoyance among exposed individuals as 40%, power of 95%, 10% absolute precision and non-response of 10%, a sample size of 100 was chosen (Basner et al., 2014). The inclusion criteria for selection of participants were: participants over 18 years of age, not using any ototoxic drugs, should not have any history of head injury, and no hearing loss. Ethical clearance for the project was taken from the Institute Ethics Committee, Post Graduate Institute of Medical Education and Research, Chandigarh, India.

3. Results

3.1. Individual source spectral analysis of noise

Table 1 depicts the individual source spectral analysis of noise. Surprisingly highest noise (sound pressure level) was recorded inside the ambulance van (87–104 dB), which carries the patient. It was observed that small ambulance van have privately fitted siren and hence have highest sound pressure level. Further, bus horn and security whistling also have sound pressure level above 90 dB. It appears that traffic inside the hospital campus (e.g. car, bus and two wheelers) dominate the environmental noise, whereas cleaning machine, television, ringing of phone and movement of trolleys dominate the indoor noise in the hospital.

Table 1
Individual spectral analysis of various noise sources.

Sources of noise	Sound pressure level (SPL)
ECG machine	74.66
Cleaning machine small	68–70
Cleaning machine large	78–80
Stretcher movement	72–73
Security whistling	92
Conversation in emergency	73–75
Car	75–78
Motorcycle	65–67
Bullet motorcycle	78–80
Bus	80–82
Auto rickshaw	70–72
Inside of small ambulance with siren	104
Inside of large ambulance with siren	87
Car horn	85–87
Bus horn	90–92
Motorcycle horn	80–82
Children sound	70–72
Loudspeaker (distant)	75–80
TV sound	76–80
Consumable trolleys	70
Substation transformer	57
Laundry machines	78–80
Incinerator	81–82
Cold freezer	58
Mobile bells	64–65
Telephone bells	80–82
Lab equipments	72–75
Chiller machine	80.5
Construction tile cutter	81
Crowd conversation in emergency	72–75
AC fan duct	75

3.2. Diurnal pattern of noise levels in and around the hospital

As per 'The Noise Pollution (Regulation and Control) Rules, 2000', the day and night time ambient air quality standards in respect of noise are 50 dB and 40 dB, respectively, in India. Equivalent sound pressure level (L_{eq}) was found higher than the permissible limits at all the sites both during daytime and night time (Fig. 1). Maximum equivalent sound pressure level (L_{max}) during the day was observed higher (>80 dB) at the emergency and around the main gate, Old hospital gate and OPD gate. L_{max} during the night was higher (>70 dB) at the emergency and around the main gate, old hospital gate and OPD gate, advanced cardiac centre, cafeteria, advanced pediatric centre and market area. Diurnal variation of sound level was maximum (>10 dB) in locations such as school, residential area, in and around the main gate and the OPD gate, cafeteria, nursing institute and old hospital only during weekdays. Minimal diurnal variation (<3 dB) was found in Library, hospital buildings like ICU-Advance cardiac centre and advance eye centre, Doctor's Hostel.

3.3. Weekday vs weekend noise pattern

Significant difference (10 dB) was observed between weekend vs weekday noise pattern at new OPD gate and old hospital during the office hours (Fig. 2). Noise pollution at main gate and OPD gate reduced only by 2 dB and 4 dB, respectively, during the daytime. Exceptionally high noise pollution was observed during weekend night at old hospital than weekday. No significant deviation was observed in noise levels at main Gate, OPD Gate at night during both weekdays and week nights.

3.4. Non-auditory impact of noise

All the respondents (100%) considered noise as a source of pollution (Table 2). More than half of the respondents were moderately sensitive to noise whereas 12.4% of them were highly sensitive to noise. Another 10.3% were very sensitive to noise. More than half of the respondents (55.6%) reported disturbance during sleeping due to noise. A total of 43.4% of respondents get disturbed during studying, whereas 38.4% of respondents feel disturbed during working hours due to loud noise (Fig. 3). Almost all the respondents (97%) regarded traffic as the major source of noise. About one-third of the respondents considered loud conversation, crowd and loud speaker as a major source of noise (Table 2). Loud music was perceived by 26% of respondents as a source of noise followed by construction work activities (16.2%), medical equipment (11.1%) and barking of dogs (11.1%). Nearly three-fourths (74%) of respondents reported irritation with loud noise, whereas 40.4% of respondents suffered from headache due to noise (Fig. 4). Less than one-third of respondents (29.3%) reported loss of sleep due to noise. On a scale of 0–10, traffic was considered as a major source of noise with a mean score of 6.8, followed by Air conditioners /Diesel generators (ACs/DGs, mean score: 4.9) as shown in Fig. 5.

4. Discussion

Table 3 shows a comparative overview of noise pollution monitoring and reported non-auditory health impacts in hospital settings. Based on Table 3, it can be concluded that sound levels in hospitals have always been found above the recommended levels, and ranges from 45 dB to above 120 dB. Similarly, the current work also observed noise levels well above the permissible standards at all the locations in and around a tertiary hospital. Further, movement of vehicles (traffic) was considered as the major source of noise.

Regarding non-auditory health impacts of noise, respondents reported irritation, headache and loss of sleep due to increased noise levels. Hospital noise can pose problems for patient safety and recovery. Further, it may also contribute to stress and burnout among hospital workers. Grumet (1993) reported a significant correlation between increasing noise levels and increased length of stay and considered noise control in a hospital a high priority. The L_{eq} in the current work exceed the recommended WHO guidelines at all the monitoring sities. The L_{eq} was also found similar to sound levels observed in other healthcare settings as depicted in Table 3. Many of these studies have reported peak hospital noise levels exceeding 85–90 dB. Hospitals are noisy

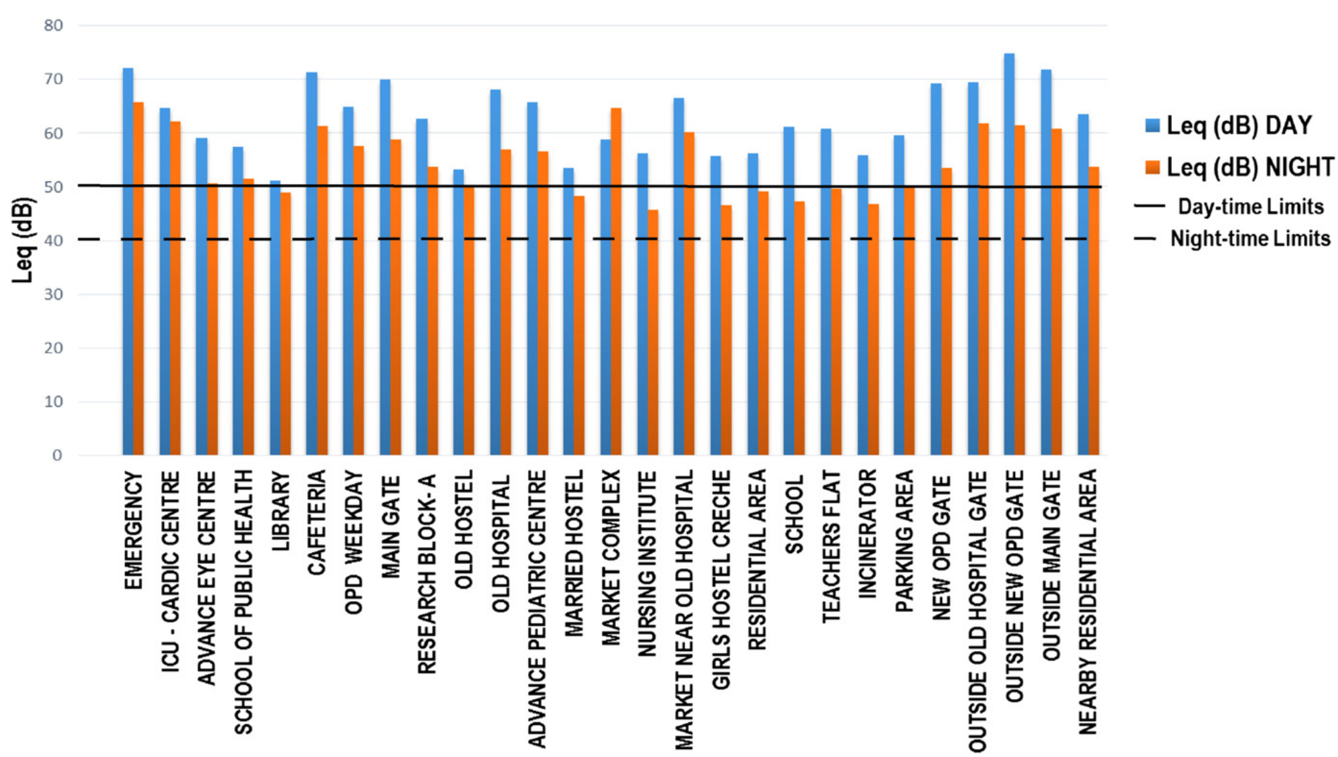

Fig. 1. Level of noise pollution in and around a medical institute.

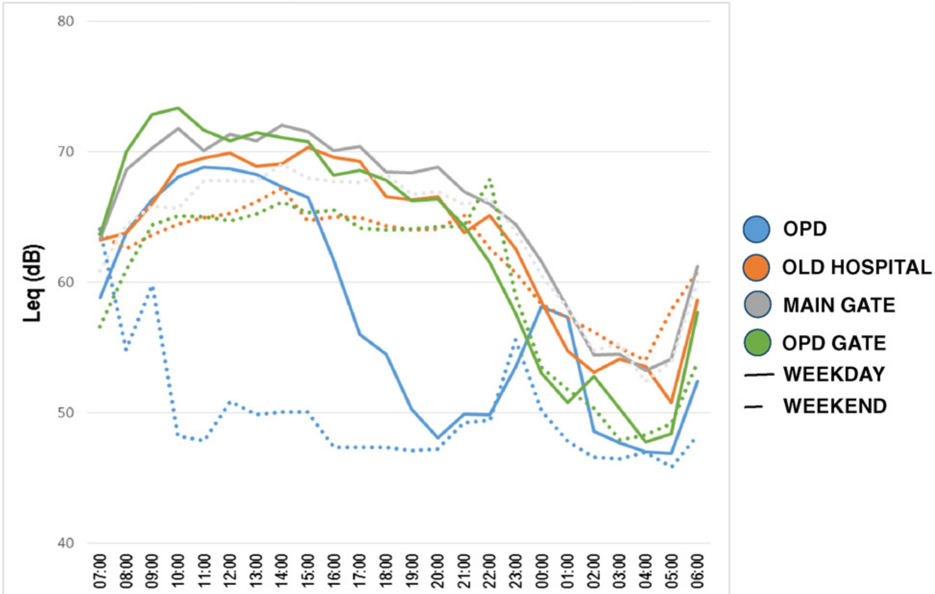

Fig. 2. Weekday vs Weekend noise level comparison.

because of multiple sources of noise and surfaces in hospitals which tend to be sound-reflecting rather than sound-absorbing (Ulrich et al., 2004). The heavy inflow of patients along with visitors and traffic (engine noise, horns and public vehicles on adjacent roads) could probably be the major contributing factors for such high noise levels at the emergency, hospital buildings and around the gates. Other possible sources of noise include conversation among health care providers and visitors, moving carts, equipments and appliances (ACs, mobile phones, alarms of instruments, power generators). The lowest noise level during daytime was found at the library whereas during the night, the library, OPD on a holiday, school, residential areas and the Nursing Institute had lowest noise levels probably due to less crowding and restricted entry. Considerable diurnal variation (>10 dB) was observed around the gates due to change in traffic flow pattern. Weekdays were found to be noisier than weekends, which might be attributed to less patient and traffic inflow during the weekends. Busch-Vishniac et al. (2005) showed that during the period 1960–2005, average day time noise in hospitals has increased from 57 to 72 dBA, whereas night time noise has increased from 42 to 60 dBA, which is a major concern for patient safety and recovery.

In the present study, more than half of the respondents reported disturbance during sleeping due to noise. There are enough evidence in the literature, both subjective and objective, for sleep disturbance by the noise (Öhrström et al., 1988). More than 90% of respondents in the study stated that they get annoyed due to noise sometimes or always. Annoyance has been reported in the literature as the most widespread and well documented subjective response to noise, which may include fear and mild anger (Cohen and Weinstein, 1981). Noise is also associated with interference in daily activities, which leads to annoyance (Laszlo et al., 2012; Taylor, 1984). Irritation and headache have been reported by a large number of respondents similar to other studies (Öhrström, 1989). It has also been observed that the more sensitive to noise the individual was, the more frequent were these symptoms (Öhrström, 1989). The fact that more than three-fourth of the respondents in the present study reported moderate or higher sensitivity to noise, it is now ringing alarming bells to face this challenge head-on rather than ignore this. The Nobel Prize Winner Robert Koch rightly predicted in 1910 that "*One day man will have to fight noise as fiercely as cholera and pest*". Less than one-third of respondents reported loss of

Table 2
Opinion of the respondents towards noise pollution.

Sr. no.	Parameter	N (%)
1	**Sensitivity towards noise**	
1.1	Highly sensitive	12.4
1.2	Very sensitive	10.3
1.3	Moderately sensitive	53.6
1.4	Mildly sensitive	21.6
1.5	Not sensitive	2.1
2	**Perceived sources of noise pollution**	
2.1	Traffic	97.0
2.2	Loud conversation	33.3
2.3	Crowd	31.3
2.4	Loud speaker	31.3
2.5	Loud music	26.3
2.6	Machines/motors/AC/DG/TV/printer	21.2
2.7	Construction work	16.2
2.8	Barking dogs	11.1
2.9	Medical equipment	11.1
2.10	Others	7.1
2.11	Cultural event	6.1
2.12	Industries	4.0
2.13	Patient trolleys	4.0

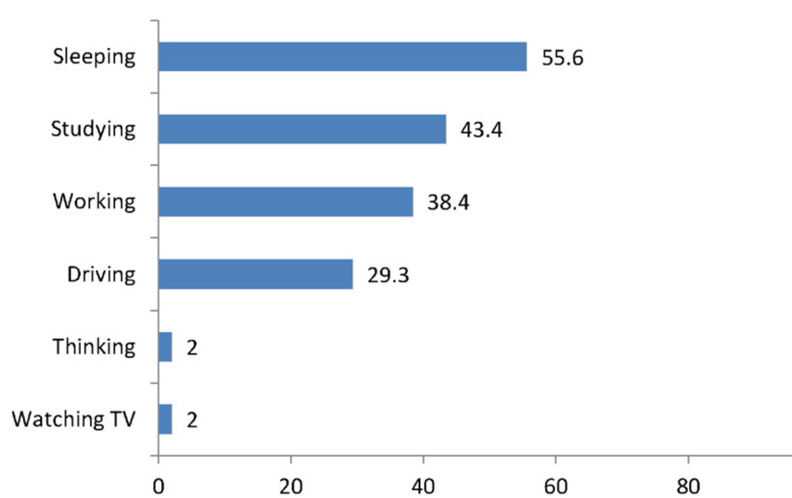

Fig. 3. Impact of noise pollution on individual activities.

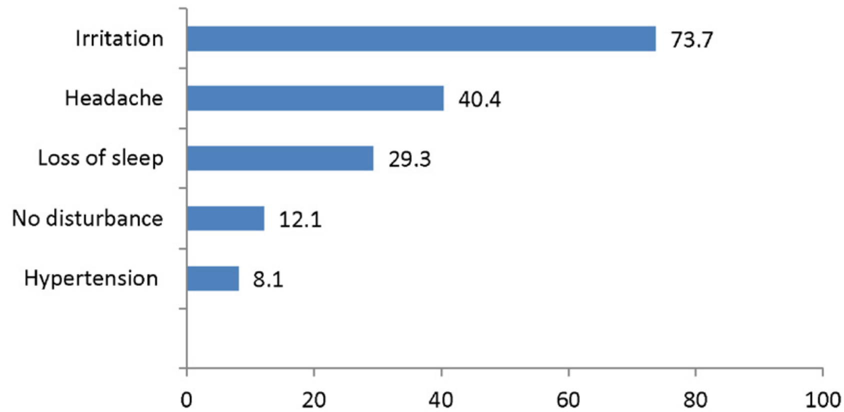

Fig. 4. Perceived non-auditory health impact of noise pollution.

sleep due to noise. Sleep deprivation has wide-ranging effects on the cardiovascular, endocrine, immune, and nervous systems causing obesity, diabetes and impaired glucose tolerance, cardiovascular disease and hypertension, anxiety disorders and depressed mood(Colten and Altevogt, 2006). Hence, non-auditory effects studied in the current work can add to the risk factors associated with non communicable diseases. Further, the recent Global Burden of Disease also highlights the increasing risk of non communicable diseases. Whereas, quiet time and improved acoustics reduces noise levels, improves sleep and have a positive impact on work environment and job strain.

5. Recommendations

Studies have shown that installing sound-absorbing ceiling tiles and panels results in reduced noise levels and perceptions of noise leading to improved speech intelligibility and reduced perceived work pressure among staff (Blomkvist et al., 2005; MacLeod et al., 2007). Single-bed rooms are probably the single most-effective strategy for reducing noise in wards (Joseph and Ulrich, 2007). Some hospitals have installed a device like a traffic light that monitors the noise level by turning from yellow to red as it rises. “Quiet Kits” with sleep masks and earplugs help patients tune out intrusive sound. Kahn et al. (1998) determined that 51% of the noise in the ICU was modifiable. He later found that by implementing simple behavior modification strategies through educational sessions and other simple measures such as metal bins replaced with plastic significantly reduced the peak noise level. A study by Ramesh et al. (2009) conducted in a tertiary hospital in India mention that simple environmental modification like fitting legs of all furniture with rubber shoes, replacing all metallic files with plastic files, keeping the phone ringer at a minimum audible level reduced the noise level significantly. Quiet time, a period of reduced controllable noise and light at preset intervals was found to significantly reduce noise levels and increase sleep hours (Dennis et al., 2010; Olson et al., 2001). Simple measures like keeping equipments and alarms away from patients, switching mobiles phones to vibrating or low volume mode, providing signs like “Quiet please”, awareness programs for staff help reduce noise (Bremmer et al., 2003). Music therapy has also been shown to have a beneficial impact on patient anxiety and a host of other physiological parameters (Cabrera and Lee, 2000). Thus, a combination of behavioral modification, administrative and engineering controls may reduce noise levels below the recommended level.

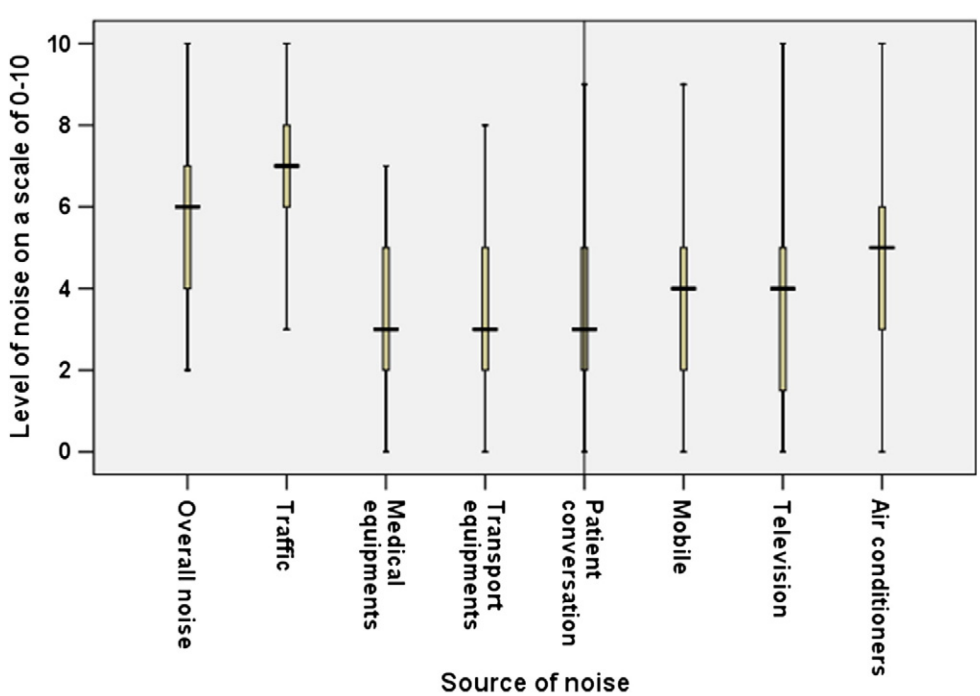

Fig. 5. Level of noise according to the source on the scale of 0–10.

Table 3
A comparative overview of noise pollution monitoring and reported non-auditory health impacts in hospital settings.

Study sites	Primary outcome/association	Key findings	References
Intermediate respiratory care unit, USA	Sleep disruption	Sound peak levels > 80 dB	Aaron et al., 1996
Intensive Care Unit, Austria	Sound pressure levels	L_{eq}60–65 dB, peak up to 96 dB	Balogh et al., 1993
Intensive coronary care, Sweden	Effects of acoustics on staff turnover, quality of patient care, and medical errors	Improved acoustics positively affected work environment, strain and pressure	Blomkvist et al., 2005
Pediatric ICU, USA	Sleep duration and pattern	Mean level 55 dB with sudden elevation up to 90 dB	Cureton-Lane and Fontaine, 1997
State psychiatric hospital, USA	Sound pressure levels	76 dB, peak up to 90 dB	Holmberg and Coon, 1999
Neonatal ICU, Canada	Ambient noise levels	61 dB, peak > 120 dB	Kent et al., 2002
Emergency department, USA	Sound pressure levels	Time weighted average 45–53, peak levels 94–11 dB	Tijunelis et al., 2005
Johns Hopkins Hospital, USA	Sound levels	Mean levels 50–60 dB	Busch-Vishniac et al., 2005
Neuro-ICU, USA	Effect of quiet time on noise levels and patients' sleep behavior	Quiet time reduces noise levels and improves sleep	Dennis et al., 2010
Pediatric ICU, USA	Sound levels and its correlation with stress and annoyance	Daytime 61 dB, night 59 dB, increases stress, annoyance and heart rate	Morrison et al., 2003
Wards in regional hospital, Tanzania	Sound pressure levels	57–59 dB, peak up to 71 dB	Moshi et al., 2010
3 General hospitals, Nigeria	Noise levels	74–89 dB in OTs, >80 dB in service areas (laundry, generator room, boiler room)	Omokhodion and Sridhar, 2003
Tertiary care hospital, South India	Sound levels, diurnal pattern	Morning-70 dB, evening-64 dB	Vinodhkumaradithyaa et al., 2008
Emergency Department, Australia	Sound levels	Sound levels 56–64 dB with diurnal variation	Short et al., 2011
Neonatal ICU, USA	Sound levels	55–63 dB	Williams et al., 2007
Operating rooms, USA	Sound levels	Highest with orthopaedic surgeries-66 dB, peak > 120 dB	Kracht et al., 2007
Post anaesthesia care unit	Sound levels and sources of noise	Mean 67 dB, $L_{eq\ max}$ 76 dB, L_{eq}min 49 dB, staff conversation caused maximum noise	Allaouchiche et al., 2002
Tertiary care hospital, Taiwan	Sound levels and sources of noise	50–68 dB in wards, <50 dB during night in surgical ICU, 98–108 in generator rooms and AC facilities	Pai, 2007
Neonatal ICU, USA	Sound levels	L_{eq}(60.44 dB range of 55–68 dB) and L_{max} (M = 78.39, range = 69–93 dB)	Krueger et al., 2005
Tertiary care hospital, North India	Sound pressure levels, individual source spectral analysis of noise, perceived non-auditory impact of noise, impact of noise on routine activities, diurnal pattern, weekend vs weekday pattern	Ambulance, bus horn and security whistling had the highest noise, significant diurnal and weekend vs weekday variation. L_{max} > 80 dB during daytime and >70 dB during night in most cites. Traffic-major source of noise, patients reported irritation, headache and loss of sleep due to noise	Present study

6. Research gaps

More research is needed to establish which noise interventions are most likely to reduce noise levels and produce favorable medical outcomes. Research is also needed to bring out ways of reducing noise through engineering of hospital structures and acoustic measures. As highlighted by Ravindra et al. (2015), air pollution is becoming an emerging public health issue due to increasing evidence of poor air quality and adverse human health effects. Hence, there is a need to investigate that how noise pollution synergistically add to the effect of air pollution.

7. Conclusions

Noise levels monitored in and around a sensitive site are well above the permissible standards. To effectively tackle hospital noise, awareness of health care staff and public is needed. There are easily modifiable sources of noise which hospitals should identify to reduce noise and its impact on health. This will help mitigating the increasing risks associated with non-communicable diseases as the non-auditory effects add to the risk factors associated with these diseases. Further, reduction in noise will provide a more pleasant and peaceful environment for patients and staff.

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