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ASSESSMENT OF NOISE POLLUTION LEVELS IN AN ACADEMIC AREA OF AN ENGINEERING INSTITUTE IN INDIA

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A B S T R A C T

Present study focuses on typical noise assessment at 29 key locations in an academic area of a college during academic and non-academic hours, and comparison with Indian standards for sensitive zone. The equivalent continuous noise levels (L_Aeq) were observed to be exceeding the permissible limits of 50 dB L_Aeq during day time and 40 dB during night time on weekday as well as weekend of classrooms, corridors, central workshop and open spaces in academic area. The average L_Aeq values for the entire academic area on weekday during day time (65.88 dB), weekday night time (47.70 dB), weekend day time (57.73 dB) and weekend night time (45.77 dB) were also observed to be 31.77 %, 19.24 %, 15.45 % and 14.43 % respectively higher than the prescribed standards for educational/ academic institutes. Further, noise maps were created by ArcGIS using Inverse Distance Weighting (IDW) technique showing noise hotspots at a glance.

1. INTRODUCTION

The Sound being a mode of communication and entertainment amongst the human beings is a normal feature of life. It may be either pleasant (i.e. music) or annoying (i.e. noise). Annoying or unwanted sound has detrimental physiological and psychological effects on people, and noise is one such sound (Mamun et al., 2017). Sound is converted to noise under its magnitude of appearance and becomes intolerable to human beings and the environment (Poddar, 2017). So, noise is usually defined as unwanted sound pollutant which produces undesirable physiological and psychological effects in an individual, by interfering with one's social activities like work, rest, recreation, sleep etc. (CPCB, 2017). Noise represents one of the leading risk factor distortions of overall health integrity, next to air pollution (WHO, 2011; Djercan et al., 2015; Harari et al., 2017). It has become a serious global environmental problem, particularly in rapidly urbanizing areas, due to development of modern technologies, industrialization, urbanization, and city traffic (Ausejo et al., 2010; Brainard et al., 2004; Ehrampoush et al., 2012; Mansouri et al., 2006; Oyedepo & Saadu, 2009). As per World Health Organization (WHO), over 5% of the world's population (i.e., 430 million people are suffering from disabling hearing loss, and it is estimated that about 700 million people (i.e., 1 in every 10 people) will be affected by 2050 (WHO, n.d.). Persistent exposure to high noise levels can cause temporary or permanent mental and physical damage to human body functions (Atkinson, 2007; Baliatsas et al., 2016; Ersoy et al., 2017; Kallankandy & Deswal, 2023; Maqsood et al., 2019). It is equally a big problem in schools and educational institutes all over the world, particularly in developing countries (Sadick & Issa, 2017; Sajin et al., 2019; Thattai et al., 2017; Vilcekova et al., 2017).

Noise directly impacts the quality of education. Students can perform better under quiet condition than under noisy condition (Massonnie et al., 2019; Slater, 1968),

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as it is difficult to have communication in a noisy environment due to the voice communication masking effect. There is a close relationship between poor mental performance, level of education, and noise levels, especially in studies that require communication, thinking and mental effort (Hussein & Al-Sulttani, 2021). The people's mental ability is affected a lot by exposure to noise for one second reduces focus for 30 seconds (Berglund et al., 1999). The effects of noise pollution in an academic environment include disturbance in teaching-learning process, difficulties in classroom discussion, speech interference, task performance, reading concentration, problem-solving, memory, increased absenteeism, health problems and mental stress (Ali, 2013; Debnath et al., 2012; Farooqi et al., 2020; Lee et al., 2017; Obot & Ibanga, 2013). High noise levels, exceeding the standard limit, in eight schools and colleges in Nagaon town in Assam (India) were reported in the range of 54 – 80 dB(A) (Debnath et al., 2012). Obot and Ibanga (2013), reported a rising trend of noise levels during the day to a peak value of 89.5 dB(A) that gradually decreased towards evening hours in the Town Campus of University of Uyo, Uyo (Nigeria). A study by Ozer et al. (2014) conducted in Ataturk University' campus in Erzurum, Turkey found that the noise level was more than 55 dB (ranging between 62 – 70 dB). In a study of educational institutes near busy traffic nodes in Chittagong city, Mamun et al. (2017) reported that teachers and students had disturbance in the teaching-learning process (60 %), difficulty in classroom discussion (25 %) and health-related issues (25 %). Hussein and Al-Sulttani (2021) reported that spatial distribution of equivalent noise levels exceeded 75 dB in the classrooms building corridor in the noon, and the noise level reached to a maximum level of more than 90 dB (with a minimum level of 60 dB) in the afternoon in the study area in Kufa University, Najaf, Iraq. Yadav et al. (2021) investigated the noise levels in Gorakhpur city in India at BRD Medical College and MMM University of Technology at various locations within the respective campuses and reported that noise levels were crossing the prescribed limits almost at all locations. Herzog et al. (2020) reported daily noise levels in classrooms and workshop as 74 dB(A) and 84-91 dB(A) in the Technical High School, Ravne, Slovania. Recent noise studies have also used geostatistical GIS techniques to represent the noise measurement values using isopleth noise maps and to find out the noise hotspots in a given area easily at a glance (Banerjee et al., 2009; Farooqi et al., 2017; Farooqi et al., 2020; Hussein & Al-Sulttani, 2021; King et al., 2012; Maqsood et al., 2019;).

In view of the growing noise pollution in educational settings and its negative impacts, the study of noise pollution has become essential in academic area of educational institutes or universities in an academic context. Therefore, the present study aimed at (i) measuring and comparing the existing noise levels during day time and night time on weekdays and weekends at various locations, and (ii) mapping noise levels of academic area of National Institute of Technology (NIT) Kurukshetra, Haryana (India). The study has also pointed the major activities/sources of noise pollution, and suggested remedial measures for the abatement of noise pollution in the academic environment.

2. MATERIALS AND METHODS

2.1 Study area

National Institute of Technology (NIT) Kurukshetra is a technical and research Institute of National Importance administered by Government of India. The Institute offers courses of study leading to B.Tech. and M.Tech. degree and research facilities leading to the degree of Ph.D., and having a total student strength of about 6,000 with an annual intake of about 2,000 students.

The Institute is located in Kurukshetra city in the state of Haryana (India) having geographic location of 76.82° eastern longitude and 29.95° northern latitude, at an altitude of 260 m above mean sea level. The campus spreads over an area of about 300 acres (1.2 sq. km.), and has been organised into functional areas/zones, such as – academic (instructional), administrative, hostel, residential, commercial (market), and sports complex. The study area/zone, i.e. the academic area is located centrally that spreads over an area of about 35.5 acres (1,43,637 m^2). The academic area houses all the academic departments/schools (namely, Civil Engineering, Mechanical Engineering, Electrical Engineering, Computer Engineering, Electronics &Communication Engineering, Business Administration, Computer Application, Physics, Chemistry, Mathematics, Humanities & Social Sciences, Renewable Energy & Efficiency, and VLSI Design & Embedded Systems), Central Workshop, Lecture Hall Complexes, Library, Centre of Computing & Networking, and open spaces/parks (Figure 1). Traffic (vehicular) movement is prohibited within the academic area, and restricted on southern, eastern and western peripheral roads around the academic/study area. However, regulatory traffic is allowed on northern road.

2.2Measurement of noise levels

An aircraftThis study was aimed for noise exposure assessment in the academic area of the Institute. Therefore, monitoring locations selected for the study included classrooms, lecture hall complexes, laboratories, library reading room, corridors, workshop, and open spaces within the demarcated academic area of the Institute. After checking and reviewing the academic area layout (map), a total of 29 sampling or representative locations (18 indoor and 11 outdoor), as shown in Figure 1, were selected for monitoring ambient noise levels in the academic area of NIT Kurukshetra during the academic session 2022-23 (Odd Semester) in the months of October – December, 2022. The indoor location means a location adjacent to the

academic facility (classroom, library reading room, laboratory, workshop or corridor) so as to observe ambient noise levels (not indoor noise levels within an enclosed area); whereas, outdoor location means a location in open space away from buildings (parks and lawns). Two typical sampling periods were selected in this study - one during academic hours during day time (08:30 am to 04:30 pm), and second during non-academic hours during night time (10:00 pm to 01:00 am) when student's activities were observed in library, central computing network facilities, etc. that are open round the clock. The selected sampling periods accounted for the most unfavorable hours during day and night time when people are exposed to noise pollution, and exclude the non-academic day time hours (06:00 am to 08:30 am and 04:30 pm to 10:00 pm) and quieter night time hours (01:00 am to 06:00 am). The European and Indian standards specify a minimum period of 5 minutes' continuous measurement per location during a monitored period (Domazetovska et al., 2020). Most of the reported studies have considered 5 to 30 minutes' continuous measurement time (Farooqi et al., 2017; Farooqi et al., 2020; Hussein & Al-Sulttani, 2021) so, the chosen measurement time in this study was 30 minutes for each observation. The observations were taken twice on any weekday (Monday to Friday) as well as on weekend (Saturday or Sunday) at each selected location during the sampling periods accounting for a total of 116 sample observations of 30 minutes each. All the samplings, one by one, were completed over different days and different times (during the academic and non-academic hours) (Obot & Ibanga, 2013; Farooqi et al., 2017; Farooqi et al., 2020; Hussein & Al-Sulttani, 2021) to ensure that the noise survey is statistically representative of the prevailing noise pollution levels in the academic area. Further, days having anamalous local circumstances like technical, cultural or sports events were avoided.

Noise pollution levels are expressed by measuring its loudness on a logarithmic decibel (dB) scale (Farooqi et al., 2020; King et al., 2012). A precision grade digital sound level meter (SLM) Model Casella CEL-620B1 (Casella, UK) Type 1 with a frequency response range of 6 Hz to 20 kHz that can measure noise levels between 0 to 140.2 dB(A) was used for all measurements during this study. The sound levels were measured as A-frequency weighting and in slow response mode setting that is ideal for educational institutions (Thattai et al., 2017). For measuring noise, the SLM was held 1.2 m above the ground level, and at the central location of selected site where sound influence would be greatest and free of any barriers to the medium and reflective surfaces. Calibration of the SLM was performed at 114 dB and A-frequency weighting, both before and after the day's measurements using Casella CEL-120/1 class-1 acoustic calibrator by following the instrument's handbook.

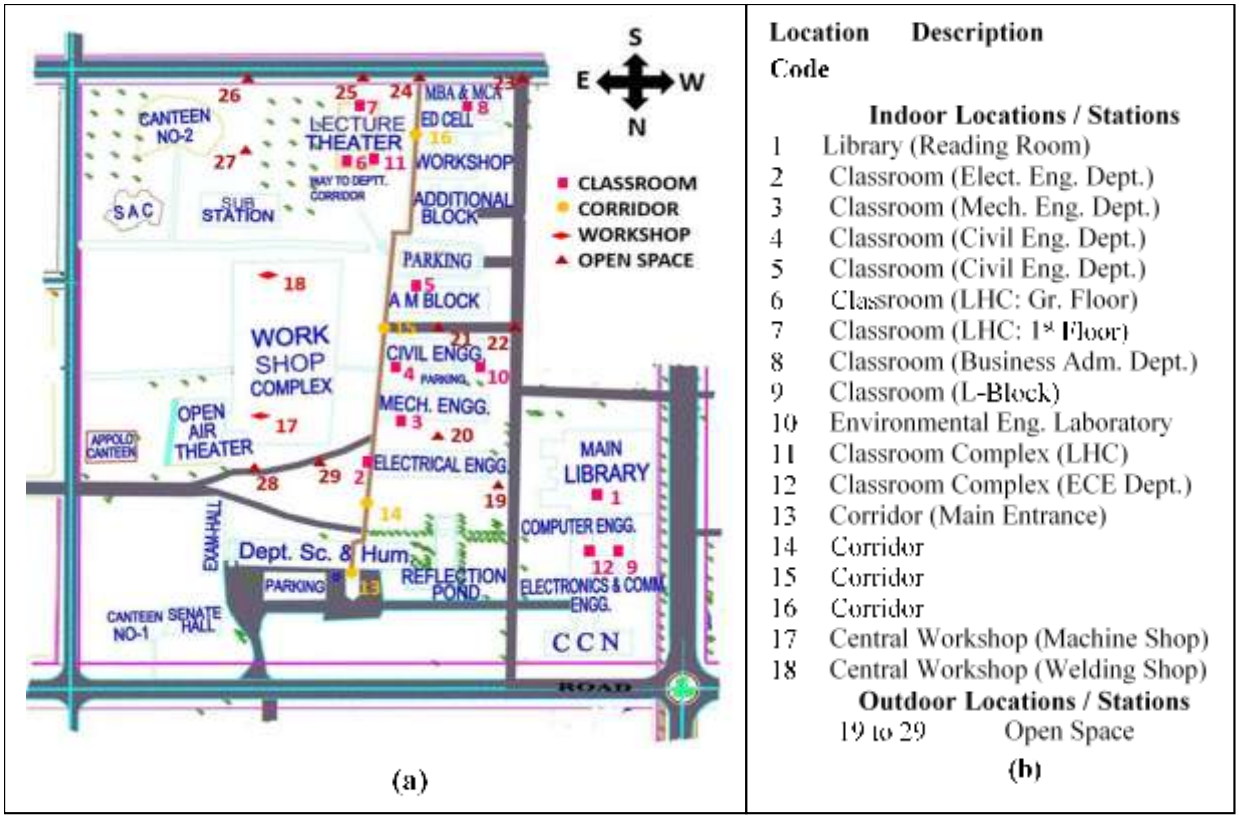

Figure 1. Study area of NIT Kurukshetra for noise monitoring. **(a)** Monitoring locations in Academic Area of the Institute, and **(b)** Description of monitoring sites.

For measurement and/or assessment of results, the following typical environmental noise measurement indices were used that were determined directly from the SLM:

L_{Aeq}: Equivalent continuous noise level with A-weighted frequency, expressed in decibels (dB)

L_{max}: Maximum A-weighted frequency noise level with a slow response (1 sec), expressed in in decibels (dB)

L_{min}: Minimum A-weighted frequency noise level with a slow response (1 sec), expressed in in decibels (dB)

L_{peak}: Highest instantaneous noise level with A-weighted frequency and no time weighting, expressed in in decibels (dB)

2.3 Statistical analysis

Descriptive statistics were applied to analyse collected noise data. The noise level data was evaluated using Microsoft Excel spread sheet. The results from the noise measurements were compared with permissible limits/standards for the two time-periods recommended by by-law for environmental noise limits in India, that is L_{Aeq}= 50 dB during day time from 06:00 am to 10:00 pm, and L_{Aeq}= 40 dB during night time from 10:00 pm to 06:00 am for academic area of universities / educational institutions categorised as sensitive zone (CPCB, 2017). The key findings have been presented in the form of tables and graphs as well.

3. RESULTS AND DISCUSSION

The analysis of results and discussion have been presented by classifying the academic area/zone of NIT Kurukshetra as:

- Classrooms, that also include library reading room and laboratory (12 locations: 1 to 12),
- Corridors (04 locations: 13 to 16),
- Central workshop (02 locations: 17 and 18), and
- Open spaces between academic buildings, such as parks, pathways, etc. (11 locations: 19 to 29).

3.1 Noise levels of classrooms

The measured noise indices at various locations have been tabulated for weekday and weekend in Table 1 and Table 2 respectively.

On weekday (Table 1), the L_{Aeq} noise levels varied from 57.30 to 71.3 dB having L_{max}, L_{min}, and L_{peak} in the range of 66.4-81.5 dB, 41.9-63.9 dB, and 86.3-114.4 dB respectively during day time. The highest noise levels (L_{Aeq}=71.3 dB) were observed at location 12 (Classroom Complex: ECE Department) possibly due to its close vicinity to the traffic crossing/junction on the main road; whereas, the lowest noise levels (L_{Aeq}=57.3 dB) at location 7 (Classroom: LHC 1st floor). During night time on weekday, the L_{Aeq} noise levels varied from 37.9 to 46.6 dB having L_{max}, L_{min}, and L_{peak} in the range of 46.9-57.9 dB, 37.2-43.5 dB, and 80.7-88.3 dB respectively. The highest noise levels (L_{Aeq}=46.6 dB) were recorded at library (reading room) due to visiting of students to library during night hours.

Table 1. Noise indices of classroom, classroom complex, library and laboratory on weekday.

Location		L_{Aeq},in dB		L_{max},in dB		L_{min}, in dB		L_{peak},in dB	
Description	Code	Day	Night	Day	Night	Day	Night	Day	Night
Library (Reading Room)	1	56.30	46.60	67.80	57.90	63.90	43.50	86.30	88.30
Classroom (Elect. Eng. Dept.)	2	64.90	41.20	72.00	49.30	60.30	39.60	90.30	83.60
Classroom (Mech. Eng. Dept.)	3	65.10	39.10	73.10	48.90	59.60	37.50	90.30	81.20
Classroom (Civil Eng. Dept.)	4	66.30	38.80	73.60	47.90	57.60	37.50	93.40	81.10
Classroom (Civil Eng. Dept.)	5	71.30	37.90	76.90	46.90	61.60	37.20	96.60	80.90
Classroom (LHC: Gr. Floor)	6	60.20	42.30	66.40	49.90	54.70	40.60	90.90	84.50
Classroom (LHC: 1st Floor)	7	57.30	39.90	68.10	49.10	41.90	37.70	97.80	81.40
Classroom (Business Adm. Dept.)	8	60.30	38.90	70.40	48.10	57.00	37.60	99.10	81.20
Classroom (L- Block)	9	68.80	38.20	76.10	47.90	60.80	37.30	94.90	80.80
Environmental Eng. Lab.	10	63.80	38.30	76.40	48.10	57.20	37.50	97.10	80.90
Classroom Complex (LHC)	11	60.40	43.10	71.10	50.10	51.10	40.60	91.80	85.90
Classroom Complex (ECE Dept.)	12	70.80	39.20	81.50	49.00	63.00	37.40	114.40	80.70
Average Noise Levels		66.47	41.18	74.94	50.80	59.67	39.17	104.12	83.34
Indian Standards or Permissible Noise Levels (Sensitive Area)		50	40						

On weekends (Table 2), the L_{Aeq} noise levels varied from 46.3 to 68.8 dB having L_{max}, L_{min}, and L_{peak} in the range of 50.1-70.8 dB, 42.1-68.1 dB, and 76.1-87.1 dB respectively during day time; whereas, the L_{Aeq} noise levels varied from 37.7 to 51.3 dB having L_{max}, L_{min}, and L_{peak} in the range of 51.2-55.7 dB, 34.1-50.2 dB, and 70.5-77.8 dB respectively during night time. The library (reading room) recorded the highest noise levels during daytime (L_{Aeq}=68.8 dB) as well as night time (L_{Aeq}=51.3 dB) due to visiting of students to library during weekends as well.

Based on L_{Aeq}, the noise levels at all locations were 7.3 to 21.3 dB (i.e., 14.6-42.6 %) above the permissible limits of 50 dB during day time; though the noise levels were within the permissible limits of 40 dB during night time except at four locations (1, 2, 6 and 11) on weekday as shown in Figure 2. On weekend, the noise levels during day time were within permissible limits of 50 dB except at locations 1, 6, 7, 9 and 12; whereas, the noise levels during night time were within permissible limits of 40 dB at all locations except location 1 (Library reading room). The library reading room, in fact was noisier during weekend due to presence of a

Table 2. Noise indices of classroom, classroom complex, library and laboratory on weekend.

Location		L_{Aeq},in dB		L_{max},in dB		L_{min}, in dB		L_{peak},in dB	
Description	Code	Day	Night	Day	Night	Day	Night	Day	Night
Library (Reading Room)	1	68.8	51.3	70.8	55.7	68.1	50.2	87.1	70.5
Classroom (Elect. Eng. Dept.)	2	49.1	39.9	55.3	53.7	44.5	34.3	85.0	74.8
Classroom (Mech. Eng. Dept.)	3	46.9	38.1	54.5	52.3	42.3	34.2	81.0	75.8
Classroom (Civil Eng. Dept.)	4	46.3	38.0	53.9	51.9	42.1	34.1	79.6	76.1
Classroom (Civil Eng. Dept.)	5	49.1	37.7	54.4	51.2	44.0	34.5	84.5	75.8
Classroom (LHC: Gr. Floor)	6	55.2	39.8	56.6	53.6	54.7	36.9	81.4	77.8
Classroom (LHC: 1st Floor)	7	51.2	39.2	57.3	53.1	50.3	36.3	78.6	77.5
Classroom (Business Adm. Dept.)	8	48.7	37.9	56.3	52.3	49.9	36.1	78.1	76.8
Classroom (L- Block)	9	62.4	37.9	63.3	52.1	61.9	36.4	83.4	76.9
Environmental Eng. Lab.	10	48.5	37.1	56.8	51.9	46.7	36.2	79.1	76.5
Classroom Complex (LHC)	11	47.1	38.9	50.1	52.6	44.5	37.5	76.1	77.5
Classroom Complex (ECE Dept.)	12	58.0	38.3	59.0	52.3	54.8	36.9	77.9	77.2
Average Noise Levels		59.57	42.50	61.78	52.89	58.74	40.90	81.49	76.41
Indian Standards or Permissible Noise Levels (Sensitive Area)		50	40						

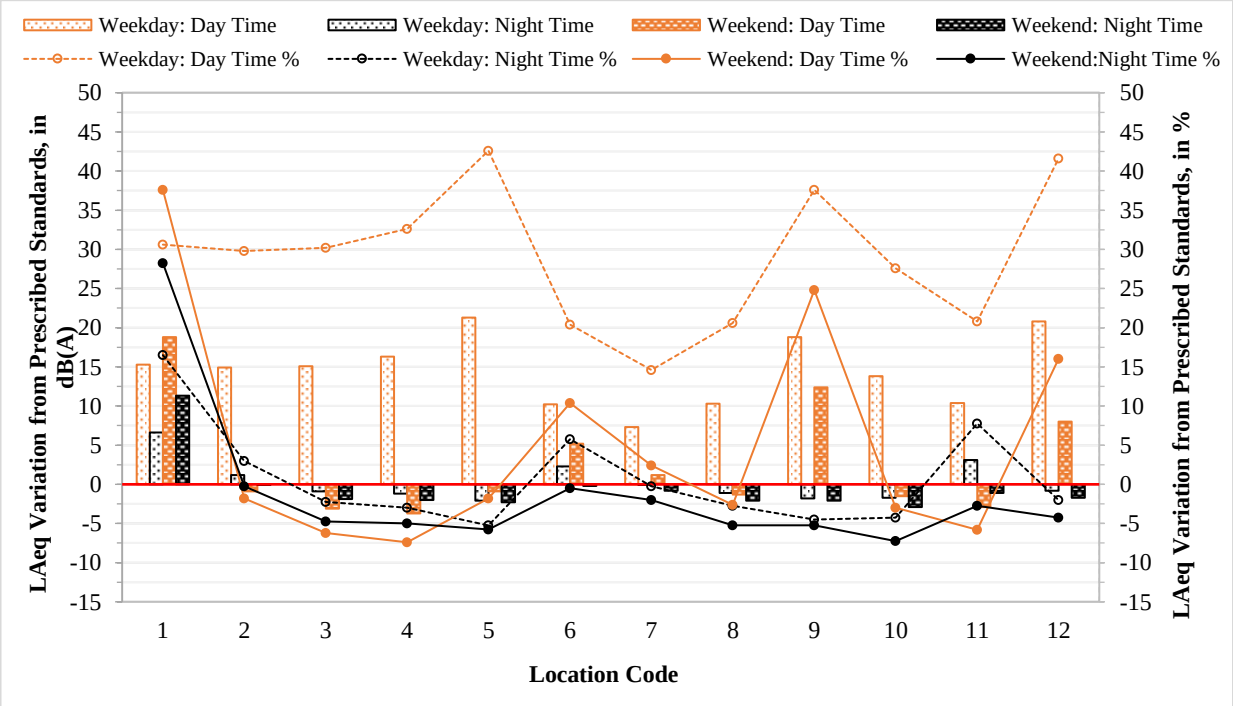

Figure 2. Noise level (L_{Aeq})) variation from prescribed standards / limits during day and night times on weekdays and weekends of classrooms, laboratories and library (reading room)

greater number of students in library during weekend around the clock.

3.2 Noise levels of corridors

The measured noise indices of corridors have been presented in Table 3 and Table 4 for weekday and weekend respectively. On weekday, the L_{Aeq} noise levels varied in a narrow range of 66.3 to 70.5 dB having L_{max}, L_{min}, and L_{peak} in the range of 73.8-79.3 dB, 49.4-60.3 dB, and 93.0-95.7 dB respectively during day time. During night time on weekday, the L_{Aeq} noise levels varied from 43.4 to 59.7 dB having L_{max}, L_{min}, and L_{peak} in the range of 50.2-71.2 dB, 41.2-50.4 dB, and 86.3-95.6 dB respectively.

On weekend, the L_{Aeq} noise levels varied in a range of 52.4 to 62.9 dB having L_{max}, L_{min}, and L_{peak} in the range of 57.1-73.6 dB, 49.6-58.7 dB, and 76.5-101.9 dB respectively during day time. During night time on weekday, the L_{Aeq} noise levels varied from 42.2 to 57.3 dB having L_{max}, L_{min}, and L_{peak}peak in the range of 56.9-62.6 dB, 36.9-52.7 dB, and 76.3-92.2 dB respectively.

Based on L_{Aeq}(Figure 3), the noise levels at all locations were 16.3 to 20.5 dB (i.e., 32.6-41.0 %) above the permissible limits of 50 dB during day time; and 3.4 to 19.7 dB (i.e., 8.5-49.25 %) above the permissible limits of 40 dB during night time on weekday. On weekend, the noise levels during day time were 2.4 to 11.60 dB (i.e., 4.8-23.2 %), and during night time 2.2 to 17.3 dB (i.e., 5.5-43.25 %) above the permissible limits. The relatively higher noise levels at station 13 on weekend and during night time on weekday may be due to traffic noise on the adjoining main road.

Table 3. Noise indices values of corridors on weekday.

Location		L_{Aeq},in dB		L_{max},in dB		L_{min}, in dB		L_{peak},in dB	
Description	Code	Day	Night	Day	Night	Day	Night	Day	Night
Corridor (Main Entrance)	13	66.30	59.70	73.80	71.20	60.00	50.40	93.00	95.60
Corridor	14	66.60	49.10	78.90	59.90	49.40	44.60	94.60	89.50
Corridor	15	69.80	47.90	79.30	60.50	57.30	46.50	95.70	87.10
Corridor	16	70.50	43.40	77.10	50.20	60.30	41.20	95.70	86.30
Average Noise Levels		68.89	54.39	77.75	65.85	58.29	46.91	94.88	91.35
Indian Standards or Permissible Noise Levels (Sensitive Area)		50	40						

Table 4. Noise indices values of corridors on weekend.

Location		L_{Aeq},in dB		L_{max},in dB		L_{min}, in dB		L_{peak},in dB	
Description	Code	Day	Night	Day	Night	Day	Night	Day	Night
Corridor (Main Entrance)	13	61.60	57.30	73.60	62.60	58.70	52.70	101.90	92.20
Corridor	14	58.50	47.90	63.30	62.50	51.00	45.30	80.00	78.90
Corridor	15	62.90	46.60	68.00	60.40	55.30	38.00	84.20	80.70
Corridor	16	52.40	42.20	57.10	56.90	49.60	36.90	76.50	76.30
Average Noise Levels		60.29	52.18	69.01	61.13	55.11	47.62	95.99	86.76
Indian Standards or Permissible Noise Levels (Sensitive Area)		50	40						

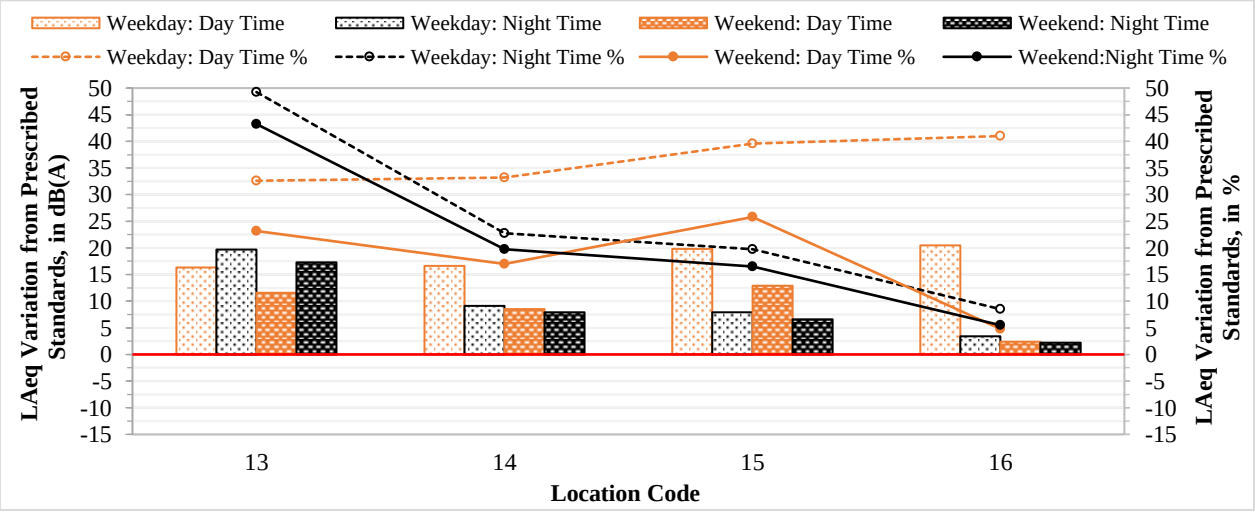

Figure 3. Noise level (L_{Aeq}) variation from prescribed standards / limits during day and night times on weekdays and weekends of corridors.

3.3 Noise levels of central workshop

The measured noise indices at Machine Shop (location 17) and Welding Shop (location 18) of the Central Workshop for weekday and weekend have been presented in Table 5 and Table 6 respectively.

Table 5. Noise indices values of central workshop on weekday.

Location		L_{Aeq},in dB		L_{max},in dB		L_{min}, in dB		L_{peak},in dB	
Description	Code	Day	Night	Day	Night	Day	Night	Day	Night
Machine Shop	17	69.70	53.90	77.20	64.50	64.30	46.10	97.90	91.20
Welding Shop	18	66.50	49.10	77.20	60.50	63.80	42.50	102.00	87.60
Average Noise Levels		68.39	52.13	77.20	62.95	64.06	44.66	100.42	89.76
Indian Standards or Permissible Noise Levels (Sensitive Area)		50	40						

Table 6. Noise indices values of central workshop on weekend.

Location		L_{Aeq},in dB		L_{max},in dB		L_{min}, in dB		L_{peak},in dB	
Description	Code	Day	Night	Day	Night	Day	Night	Day	Night
Machine Shop	17	56.90	47.10	67.90	61.50	52.90	41.30	90.90	77.40
Welding Shop	18	52.30	46.50	66.80	60.50	49.90	40.50	88.90	40.20
Average Noise Levels		55.18	46.81	67.38	61.03	51.65	40.92	90.01	74.39
Indian Standards or Permissible Noise Levels (Sensitive Area)		50	40						

On weekday (Table 5), the L_{Aeq} noise levels varied in a narrow range of 66.5 to 69.7 dB having L_{max} of 77.2 dB, and L_{min} and L_{peak} in the range of 63.8-64.3 dB and 97.9-102.0 dB respectively during day time. During night time on weekday, the L_{Aeq} noise levels varied in narrow range of 49.1 to 53.9 dB having L_{max}, L_{min} and L_{peak} in the range of 60.5-64.5 dB, 42.5-46.1 dB, and 87.6-91.2 dB respectively.

On weekend (Table 6), the L_{Aeq} noise levels varied in a narrow range of 52.3 to 56.9 dB having L_{max}, L_{min} and L_{peak} in the range of 66.8-67.9 dB, 49.9-52.9 dB, and 88.9-90.9 dB respectively during day time. During night time on weekday, the L_{Aeq} noise levels varied narrowly within 46.5 to 47.1 dB having L_{max}, L_{min} and L_{peak} in the range of 60.5-61.5 dB, 40.5-41.3 dB, and 40.2-77.4 dB respectively.

Based on L_{Aeq} (Figure 4), the noise levels at both the locations were 16.5 to 19.7 dB (i.e., 33.0-39.4 %) above the permissible limits of 50 dB during day time; and 9.10 to 13.90 dB (i.e., 22.75-34.75 %) above the permissible limits of 40 dB during night time on weekday. On weekend, the noise levels during day time were 2.3 to 6.9 dB (i.e., 4.6-13.8 %), and during night time 6.5 to 7.1 dB (i.e., 16.25-17.75 %) above the permissible limits.

3.4 Noise levels of open spaces

The measured noise indices of open spaces between the academic buildings for weekday and weekend have been presented in Table 7 and Table 8 respectively. On

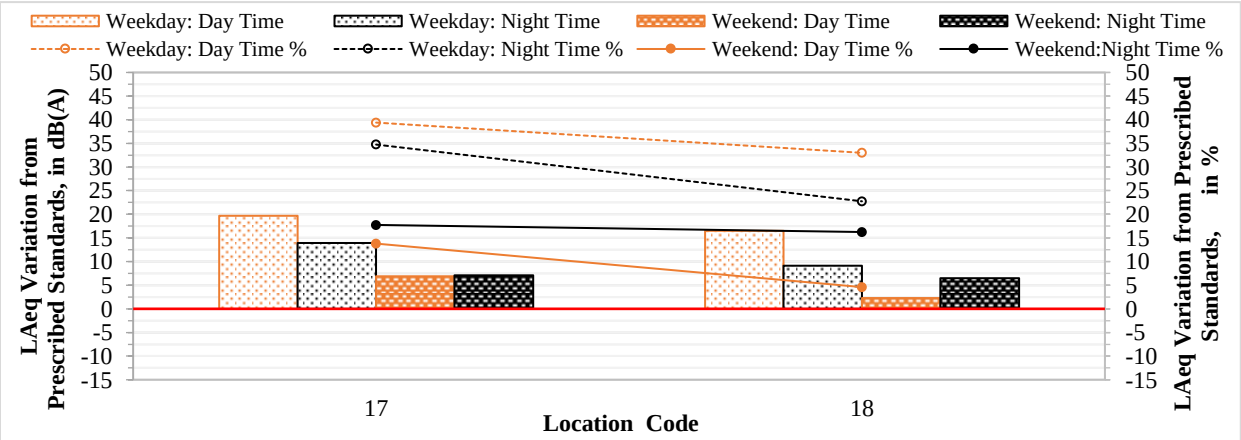

Figure 4. Noise level (L_{Aeq}) variation from prescribed standards / limits during day and night times on weekdays and weekends of central workshop.

weekday (Table 7), the L_{Aeq} noise levels varied in the range of 50.1 to 70.2 dB having L_{max}, L_{min} and L_{peak} in the range of 51.7-77.3 dB, 43.0-59.2 dB and 72.2-98.0 dB respectively during day time. During night time on weekday, the L_{Aeq} noise levels varied from 38.1 to 44.7 dB having L_{max}, L_{min} and L_{peak} in the range of 47.9-53.1 dB, 37.1-42.7 dB, and 80.2-86.5 dB respectively.

On weekend (Table 8), the L_{Aeq} noise levels varied in a range of 44.3 to 55.0 dB having L_{max}, L_{min} and L_{peak} in the range of 45.1-58.1 dB, 42.9-51.4 dB, and 60.8-89.1 dB respectively during day time. During night time on weekday, the L_{Aeq} noise levels varied within 37.8 to 45.6 dB having L_{max}, L_{min} and L_{peak} in the range of 51.6-64.8 dB, 35.9-41.6 dB, and 75.2-103.7 dB respectively.

During day time, the noisier open spaces were at locations 24 and 25 on weekday and 21, 23, 25 & 29 on weekend. During night time the noisier open spaces were at locations 21, 20, 19 & 29 on weekday as well as weekend. The possible reason of high noise levels at 21, 23, 24 and 25 may be movement of students on the road/pathway that leads to boys and girls hostel complexes on either side; and at 19 and 20 due to their close proximity to library.

Based on L_{Aeq} (Figure 5), the noise levels in open spaces on weekday were just 0.1 to 4.2 dB (i.e., 0.20-8.40 %) above the permissible limit of 50 dB during day time, except at stations 24 and 25 where the noise levels were 20.2 dB (40.4 %) and 15.7 dB (31.4 %) higher than the permissible limit. On weekends during day time, the noise levels were within the permissible limit at 6 locations, and marginally higher by 0.4 to 5.0 dB (0.8-10.0 %) than the permissible limit at other 5 stations.

However, the noise levels during night on weekday as well as weekend were within permissible limits of 40 dB at 7 same stations, and marginally higher by 0.2 to 5.6 dB (0.5-14.0 %) than the permissible limit at other 4 stations.

Table 7. Noise indices values of open spaces on weekday.

Location		L_{Aeq},in dB		L_{max},in dB		L_{min}, in dB		L_{peak},in dB	
Description	Code	Day	Night	Day	Night	Day	Night	Day	Night
Open Space	19	50.10	41.10	62.80	49.10	45.10	39.20	92.00	83.40
Open Space	20	53.00	42.90	55.30	50.20	51.70	40.80	72.20	84.30
Open Space	21	50.20	44.70	51.70	53.10	48.50	42.70	83.20	86.50
Open Space	22	51.60	38.30	65.30	48.20	43.00	37.60	83.60	80.80
Open Space	23	53.50	38.70	62.20	48.50	46.80	38.10	98.00	80.90
Open Space	24	70.20	38.20	77.30	48.10	59.20	37.10	95.10	80.30
Open Space	25	65.70	38.70	69.90	48.60	53.60	37.50	85.90	80.80
Open Space	26	53.30	39.30	63.00	49.70	48.60	38.70	76.90	81.70
Open Space	27	51.80	39.20	62.10	49.50	43.80	38.50	75.90	81.50
Open Space	28	54.20	38.10	57.50	47.90	50.00	37.10	80.10	80.20
Open Space	29	52.40	40.30	58.30	48.90	49.90	39.10	76.60	82.40
Average Noise Levels		61.56	40.52	68.38	49.52	51.82	39.11	90.45	82.54
Indian Standards or Permissible Noise Levels (Sensitive Area)		50	40						

Table 8. Noise indices values of open spaces on weekend.

Location		L_{Aeq},in dB		L_{max},in dB		L_{min}, in dB		L_{peak},in dB	
Description	Code	Day	Night	Day	Night	Day	Night	Day	Night
Open Space	19	47.70	40.70	49.00	54.60	45.10	36.80	63.20	75.20
Open Space	20	49.20	41.80	49.80	55.30	45.60	37.70	67.90	76.50
Open Space	21	55.00	45.60	58.10	64.80	51.30	41.60	89.10	103.70
Open Space	22	49.50	38.40	52.40	52.40	47.10	36.90	77.30	77.30
Open Space	23	53.00	38.50	57.60	52.90	47.60	37.10	87.60	77.40
Open Space	24	49.10	38.10	52.70	52.10	47.80	36.50	78.30	77.20
Open Space	25	52.50	38.40	57.90	52.30	51.40	36.80	85.50	77.40
Open Space	26	50.40	39.80	57.30	53.30	48.60	37.70	82.90	78.40
Open Space	27	47.60	39.50	56.90	53.10	42.90	37.50	80.10	78.20
Open Space	28	44.30	37.80	45.10	51.60	43.60	35.90	60.80	76.50
Open Space	29	52.40	40.20	57.00	53.60	50.00	38.50	85.10	79.60
Average Noise Levels		50.97	40.57	55.53	56.70	48.19	37.84	83.56	93.39
Indian Standards or Permissible Noise Levels (Sensitive Area)		50	40						

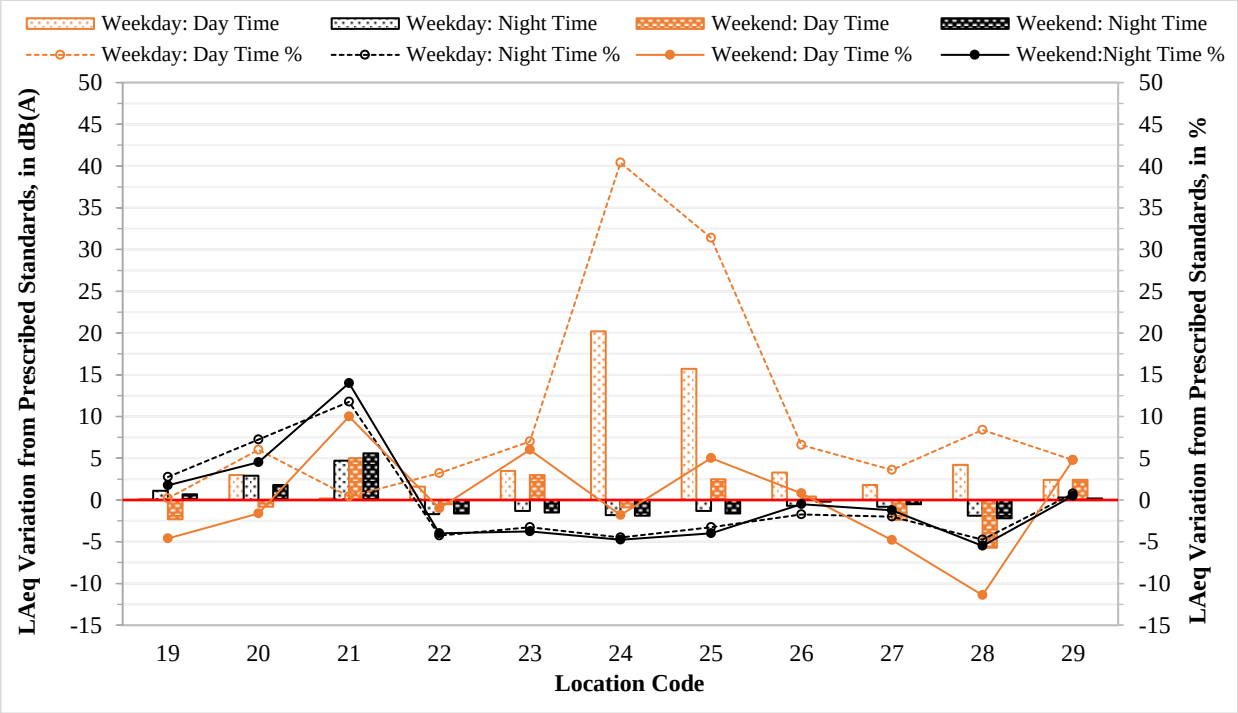

Figure 5. Noise level (L_{Aeq}) variation from prescribed standards / limits during day and night times on weekdays and weekends of open spaces.

3.5 Average noise levels of classified academic areas

In order to have a broad and overall picture of the noise levels in the four classified academic spaces (namely classrooms, corridors, central workshop, and open space) together with the entire academic area of the Institute, the average noise indices have been compared with the noise standards in Figure 6. The average L_{Aeq} values on weekday during day time of classrooms, corridors and central workshop were more or less same (66.47, 68.69 and 68.39 dB), but fairly low (7 to 10 %) in open space (61.56 dB). During night time, the classrooms were quieter (41.18 dB) than corridors (54.39 dB) and central workshop (52.13 dB); whereas the open space had the lowest noise levels (40.52 dB) about 1.6 to 25.45 % lower noise levels. The average L_{Aeq} values on weekend during day time of classrooms, corridors and central workshop were more or less same (59.57, 60.29 and 55.18 dB), but fairly low (7.6 to 15.5 %) in open spaces (50.97 dB). During night time, the classrooms were quieter (42.50 dB) than corridors (52.18 dB) and central workshop (46.81 dB); whereas the open space had the lowest noise levels (40.57 dB) about 7.64 to 15.47 % lower noise levels. However, the

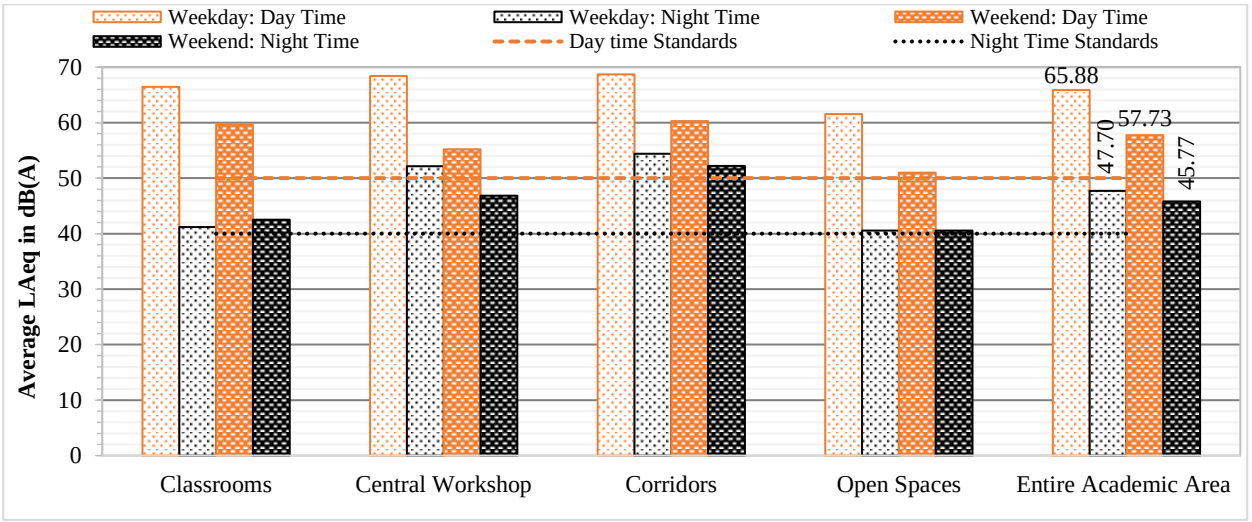

Figure 6. Average noise levels (L_{Aeq}) in the academic area of NIT Kurukshetra.

noise levels were exceeding the permissible limits of 50 dB and 40 dB during day time and night time respectively on weekday as well as weekend.

The average L_{Aeq} values for the entire academic area (including all the 29 locations) of National Institute of Technology Kurukshetra (Figure 6) on weekday during day time (65.88 dB), weekday night time (47.70 dB), weekend day time (57.73 dB) and weekend night time (45.77 dB) were observed to be 31.77 %, 19.24 %, 15.45 % and 14.43 % respectively higher than the prescribed standards of 50 dB during day time and 40 dB during night time for educational/ academic institutes in India.

The results of the present study have been compared with other noise assessment studies of educational institutes and are presented in Table 9, although with constraints such as – varying assessment periods; weekday-weekend variation or combination; academic area only or entire campus that may include residential and commercial areas; etc.

The findings off the above tabulated studies show that average noise levels in all the educational institutes were above the WHO's strict requirements of 50 dB during day and 40 dB during night (Papageorgiou et al., 2020).

unmeasured locations based on the values of surrounding measured locations. The method calculates the weighted average of the measured values, where the weights decrease as the distance from the predicted location increases and represented by equation (1).

$$Z_p = \frac{\sum_{i=1}^{n} w_i \times Z_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

where, Z_p is the estimated value, w_i is assigned weight, n is the number of measured values.

Based on reported studies of similar nature (Hussein & Al-Sulttani, 2021; Obot & Ibanga, 2013), the noise levels (L_{Aeq}) of all the sampling sites of academic area of NIT Kurukshetra were used as the input data in preparing the representative noise maps for typical academic hours (08:30 am to 04:30 pm) during day time and non-academic hours (10:00 pm to 01:00 am) during night time when students' activities were buzzing in library, center of computing network, etc. for weekday and weekend, as shown in Figure 7.

A glance at the noise maps of day time (weekday as well as weekend) showed noise hotspots in and around classroom complex: ECE Department (locations 12 and 9), along the corridor (locations 13, 14, 15, 16 and 24),

Table 9. Comparison of reported noise levels in educational institutes.

S. No.	Educational institute	Monitored area	L_{Aeq} in dB (Average or Range)	Source
1	Kufa University,Najaf, Iraq	Classrooms& building corridor	70 morning hours 75 noon hours 60-90 afternoon hours	Hussein & Al-Sulttani (2021)
2	MMM University of Technology, Gorakhpur, India	Campus	~ 42-62 day & night time	Yadav et al. (2021)
3	Technical High School,Ravne, Slovania	Classrooms Workshop	74 day time 84-91 day time	Herzog et al. (2020)
4	Ataturk University' campus, Erzurum, Turkey	Campus	62-70 day time	Ozer et al. (2014)
5	Town Campus of University of Uyo, Uyo, Nigeria	Campus	89.5 day time	Obot & Ibanga (2013)
6	Schools and colleges (8 nos.), Nagaon, Assam, India	Campus	54-80 day time	Debnath et al. (2012)
7	University of Jos, Nigeria	Campus	53.4-138.5 day time	Papageorgiou et al. (2020)
8	*National Institute of Technology Kurukshetra, India*	*Academic area of the campus*	*Weekday: 65.88 day time* *47.70 night time* *Weekend: 57.73 day time* *45.77 night time*	*Present study*

3.6 Noise maps of academic area/zone of the Institute

The representative spatial noise maps of academic area of NIT Kurukshetra were created using ArcGIS. For this, Inverse Distance Weighting (IDW) technique is used to draw spatial distribution diagrams of noise levels (Akintunde et al., 2020; Ameen et al., 2021; Nasser et al., 2023). IDW is used to evaluate values at

and in the central workshop (locations 17 and 18); whereas, during night time (weekday as well as weekend) the noise hotspots were observed in and around at location 24 (Corridor: main entrance), location 1 (Library: reading room), and central workshop (on weekend only).

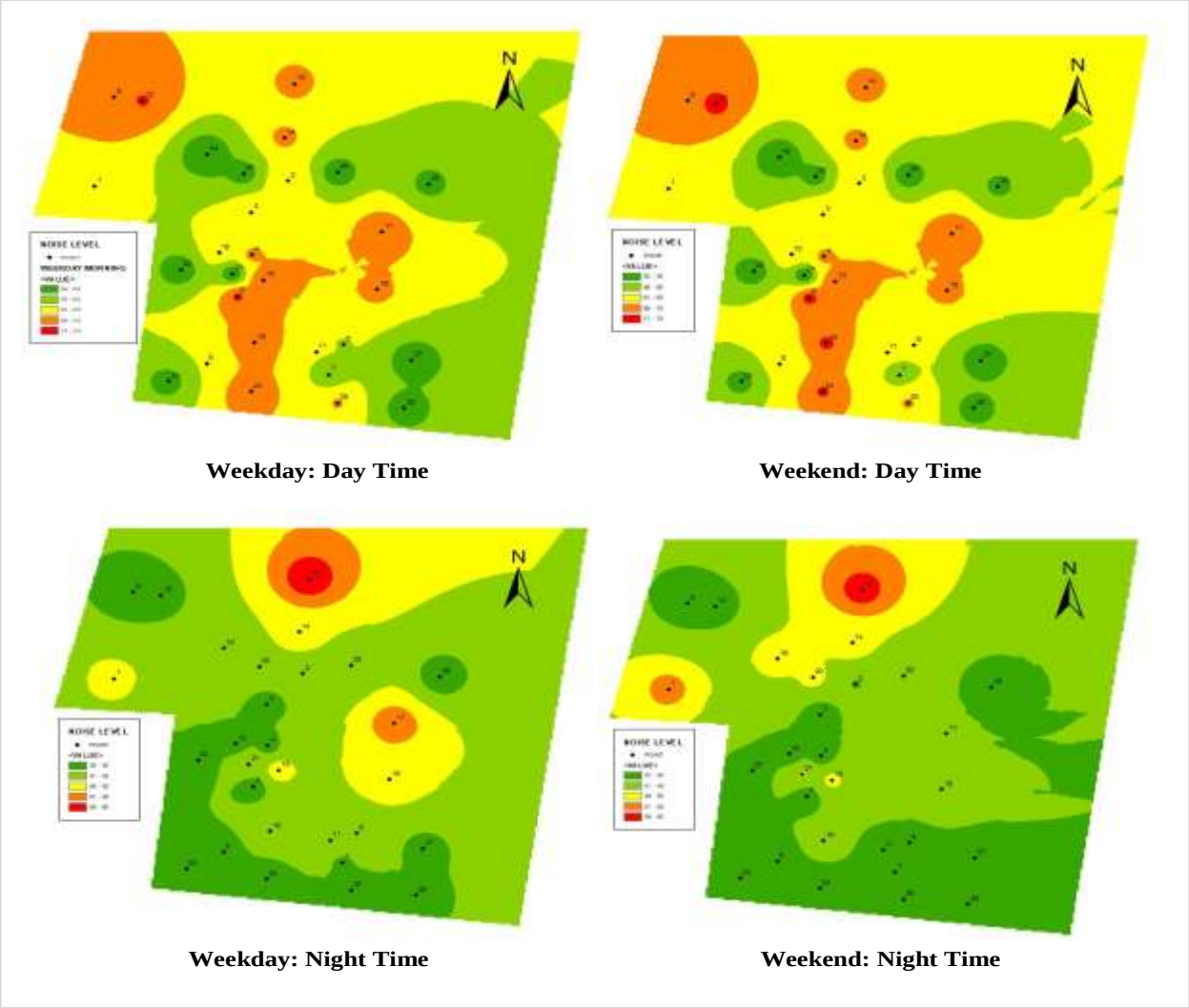

Figure 7. Interpolation of noise level of academic area of NIT Kurukshetra.

4. CONCLUSIONS

Based on the present study, it is revealed that noise levels of classroom, laboratories, workshop, corridors and open spaces located within the demarcated academic area of NIT Kurukshetra are found crossing the prescribed or permissible noise levels for educational institutes in India as well as WHO's standards.

The average L_{Aeq} values for the academic area on weekday during day time (65.88 dB), weekday night time (47.70 dB), weekend day time (57.73 dB) and weekend night time (45.77 dB) were also observed to be 31.77 %, 19.24 %, 15.45 % and 14.43 % respectively higher than the prescribed standards for educational/ academic institutes. The main causes of noise pollution include students' activities in the academic area (particularly movement in the corridors), people speaking loud, inadequate isolation of classrooms, activities outside the academic area (such as traffic on the peripheral northern road around the academic area, noise form neighbourhood and loud music during extra-curricular activities), low awareness among people, and non-compliance with legal obligations.

Based on the results of present study, following specific mitigation measures are suggested to control the high noise levels in the academic area of NIT Kurukshetra–

- Arranging special rooms where students could wait during their free time.
- Making adjustment in scheduling the classes so as to minimise the students' movement in corridors.
- Use of natural sound barriers and absorbers (i.e. layered plantation) in open spaces in and around academic area.
- Use of sound absorbers (such as panels, curtains, etc.) in classrooms, laboratories and workshop.
- Windows be made double-glazed, and repairing the damaged ones to make them airtight.
- Regular maintenance of machines or equipment, and enclosures for heavy machines particularly in workshop.
- Thick floor coverings in corridors so as to absorb the sound of passers-by in the corridor adjoining the classrooms.

- Raising awareness among the student and staff.

Further, general measures that may be followed during planning phase are also suggested for noise abatement in educational institutes as under –

- Due attention to the layout of classrooms and related facilities during planning.
- Adequate open space to be left between academic area and roads/noise-sources so as to provide a noise shield to the academic premise during planning.
- Restriction on traffic movement in and around academic area.
- Sound masking techniques, that is addition of natural sound (such as water fountains) or artificial sound into an environment to cover up effects of unwanted noises can be employed.

For further research in this area, it is recommended that noise assessment should be done for entire university/institute campus encompassing hostels, residences, market, etc., along with traffic noise assessment. There is requirement for further research in this area, including more measurement points for higher granularity, real-time monitoring and additional detailed subjective analysis for the noise exposure.

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