Urban noise assessment and its nonauditory health effects on the residents of Chiniot and Jhang, Punjab, Pakistan

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Abstract

Elevated noise level is an emerging global problem. Therefore, the present work is conducted that can improve, increase, and integrate the already known issue in literature with new information coming from an emerging country such as Pakistan. The objectives of this study were (i) to assess the urban noise levels and traffic density of Chiniot and Jhang and (ii) to determine nonauditory health effects of noise levels on the residents of both cities. Noise levels were examined from 181 locations (103 from Jhang and 78 from Chiniot) and categorized into hospitals, educational, religious and recreational, residential, industrial areas, and traffic intersections. A-weighted noise level measurements were taken using an integrated sound level meter which recorded short-term road traffic noise continuously for 15 min at each location (LA_{eq15}). The urban noise data showed 82% of the sites in Jhang ($LA_{max} = 103$ dB) and 95% in Chiniot ($LA_{max} = 120$ dB) exceeded the noise limits set by the National Environment Quality Standard of Pakistan (NEQS-Pak) and World Health Organization (WHO). Moreover, higher intensity of noise levels ($LA_{eq15} \geq 100$ dB) was recorded in Chiniot (17 sites) than in Jhang (1 site). Regression analysis showed a relatively strong relationship of traffic density with noise at Chiniot ($R^2 = 0.48$) compared to Jhang ($R^2 = 0.31$). However, spatial variability of noise with traffic density was observed in both cities. Survey study revealed that all the respondents in Jhang and Chiniot suffered from many noise-related health problems such as annoyance (53 and 51%), depression (45 and 47%), dizziness (61 and 65%), headache (67 and 64%), hypertension (71 and 56%), hearing loss (53 and 56%), physiological stress (65 and 65%), sleeplessness (81 and 84%), and tinnitus (70 and 62%) due to noise, respectively. We conclude that noise levels are higher in Chiniot primarily due to high road traffic and secondarily due to high population density. It is recommended that vehicle maintenance and family and urban planning could be effective measures to reduce urban noise levels.

Keywords Health outcomes · Noise · Regression analysis · Traffic density · Urban environment

Introduction

The elevated urban noise levels are recognized as a major problem for the quality of life in metropolitan cities all over the world (Ozer et al. 2009). As an important environmental element with social and esthetic attributes, the quality and intensity of sounds produced are two of the most important factors for environmental perception (Brown and Muhar 2004; Kang 2006; Jeon et al. 2011; Zhang et al. 2017). Noise is mainly produced from industrial processes, traffic vehicles, railway, air traffic, construction, and domestic noise (Braat-Eggen et al. 2017; Hahad et al. 2018; Gagliardi et al. 2018; Farooqi et al. 2020b). Noise levels are primarily increased due to an increase in the number of vehicles on roads; however, there are many factors manipulating the level of traffic noise such as vehicle type and their condition, quality of roads, vehicle density and their physical state, and weather conditions (Licitra et al. 2015; Wolniewicz and Zagubień 2015). Road, railway, and air traffic noises are the most impacting noise sources affecting human modern lifestyle

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(Ruiz-Padillo et al. 2016; Licitra et al. 2016, Licitra et al. 2019; Gagliardi et al. 2018; Brink et al. 2019); however, several parameters are affecting noise emission from them. For instance, road traffic noise emissions depend upon road stretches (Ruiz-Padillo et al. 2016), type of vehicle engine and tire model (Licitra et al. 2017), pavement aging (Licitra et al. 2019), pavement texture (del Pizzo et al., 2020, b), and the behavior of drivers towards low or high honking (del Carmen et al., 2020). Noise emitted from these sources is annoying and disturbing people in their daily life activity (Auger et al. 2018; Javaherian et al., 2018; Mahmud and Basak, 2019; Farooqi et al., 2020a). Normal people can bear the noise up to 80 dB for a shorter period of time, but it may damage the nerves directly if it exceeds that limitation (Purwaningsih et al. 2018). It is thought that the excessive noise levels in the urban environment are due to the industries (Bamane et al. 2019; Zeydabadi et al. 2019), community noise (Picaut et al. 2019; Bridger et al. 2019; Wilson 2019), and traffic on the roads (Cramer et al., 2019; Jørgensen et al. 2019; Paiva et al. 2019; Cai et al. 2019). It was observed from the previous studies that many sites in Faisalabad, Pakistan, have $LA_{eq} > 100$ dB (24 h), which were exceeding the permissible limits of the Pakistan Environmental Protection Agency (Farooqi et al. 2017). Urban noise is an issue not only in Pakistan, but also in most parts of the world. For instance, a pilot study has been conducted in seven big cities of India; the majority of sites had noise levels between 75 and 90 dB in commercial areas (permissible limit is 65 dB), 67 and 93 dB in industrial zones (permissible limit is 75 dB), 75 and 85 dB in residential areas (permissible limit is 55 dB), and 60 and 90 dB in silent zones (permissible limit is 50 dB) (Garg et al. 2016). Same patterns of urban noise levels were reported in London (Tonne et al. 2018), and up to 110-dB noise levels were recorded in subways in Hong Kong which were exceeding the permissible levels of 70 dB set by the World Health Organization (WHO; Xu et al. 2019). It is also reported that urban noise significantly affects property prices by 24.4% (Zheng et al., 2020). The main causes of increased urban noise levels are the traffic (Ruiz-Padillo et al., 2016; Licitra et al., 2019), and its increasing density in the cities due to population increase growth (Cai et al. 2019). Traffic vehicles use horns openly which produce noise more than industrial processes do (Fecht et al. 2016; del Carmen et al., 2020). Increased noise levels due to traffic cause different human health interventions like hypertension (Münzel and Sørensen 2017; Hahad et al. 2018), headache (migraine) (Ishikawa et al. 2019), tinnitus (Shore and Wu 2019; Wang et al. 2019), hearing loss (Kujawa and Liberman 2019; Defourny et al. 2019), and sleep disturbances (Brink et al. 2019). According to a report by WHO, 45,000 DALYs (disability-adjusted life years) are lost in European citizens because of noise-induced health effects, 903,000 DALYs because of noise-induced sleep disturbance, 61,000 DALYs because of noise-induced cardiovascular

disease, and 22,000 DALYs because of tinnitus (Münzel and Sørensen 2017).

The Environmental Noise Directive 2002/49/EC has legally bound Europe and the member states to furnish environmental noise mapping and devise an action plan for noise management emitted from >3 million vehicles, >30,000 trains, and >50,000 air crafts in a year (United Nations 2018). Intent to live in urban areas has been increased across the continents; today, 82% of the population of North America, 75% of Europe, and 51% of Asian are living in cities (United Nations 2018); therefore, assessment of population exposure to noise is important in the vicinity of urban environment. Noise level assessment and their effect on human health have been extensively studied in developed countries; however, scanty information is available in developing countries. In Pakistan, urban noise is affecting the citizen's health with the same pace, but the noise levels and their effects are not studied in most cities in the country. Therefore, the present study was conducted (i) to assess the urban noise levels and traffic density of Chiniot (new civilization) and Jhang (old civilization), (ii) survey-based assessment of nonauditory health effects of noise on the residents of both cities, and (iii) production of baseline data in the form of geographic maps through modern software technologies (ArcGIS and XLSTAT) for government considerations and public awareness. This study could also help govt. agencies in decision making for the management of noise levels and its health impacts on residents of targeted cities.

Materials and methods

Geographic and demographic features of the study area

Jhang and Chiniot are the developing cities of Punjab, Pakistan. Chiniot was a tehsil of district Jhang but now it is an independent district of Punjab. Chiniot is densely populated (524.9 persons/km^2) as compared to Jhang (431.9 persons/km^2). According to a recent census in 2017, Jhang has 2.74 and Chiniot has a 1.36 million population with an annual increasing growth rate of 2.04 and 1.36%, respectively (Table 1). Consequently, urban noise is increasing day by day. Traffic density is the main factor which contributes to increasing urban noise. More than 63% (Jhang) and 68% (Chiniot) of passengers travel within these cities using motorbikes, cars, and buses, which are the significant factors that produce noise and influence inhabitants. This study compiles the basic data about urban noise levels, traffic density, and its impact on residents of both cities. Figure 1 describes all the sampling locations for urban noise level determination of Jhang (green) and Chiniot (yellow) cities.

Table 1 Geographic and demographic features of Chiniot and Jhang during the study period

Information	Unit	Information	
		Chiniot	Jhang
Population (2017 census)	Millions	1.37	2.743
Annual population growth rate	%	1.86	2.04
Rank according to the population in Pakistan	-	28	18
Geographical area	km^2	26.10	63.53
Population density	No. of persons km^{-2}	524.9	431.9
Latitude	-	31° 43′ 10″ N	31° 16′ 10″ N
Longitude	-	72° 59′ 3″ E	72° 18′ 58″ E
Height from sea level	M	179	158
Annual rainfall	Mm	336	679
Average temperature during winter	°C	9 ± 4	11 ± 4
Humidity	%	68.8 ± 4	65.3 ± 4
Wind speed	km h^{-1}	7.3 ± 1.9	6.8 ± 1.9

Measurement of noise levels

Field measurements were taken during September 2019 by a sound level meter (SLM) for obtaining data about short-term road traffic noise continuously for 15 min at each location (LA_{eq15}) and traffic densities (T_f) in Jhang (103 locations comprised of traffic intersections [34], commercial places [6], educational institutes [18], hospitals [10], residential areas [18], religious and recreational areas [9], and industrial areas [8]) and Chiniot (78 locations comprised of traffic
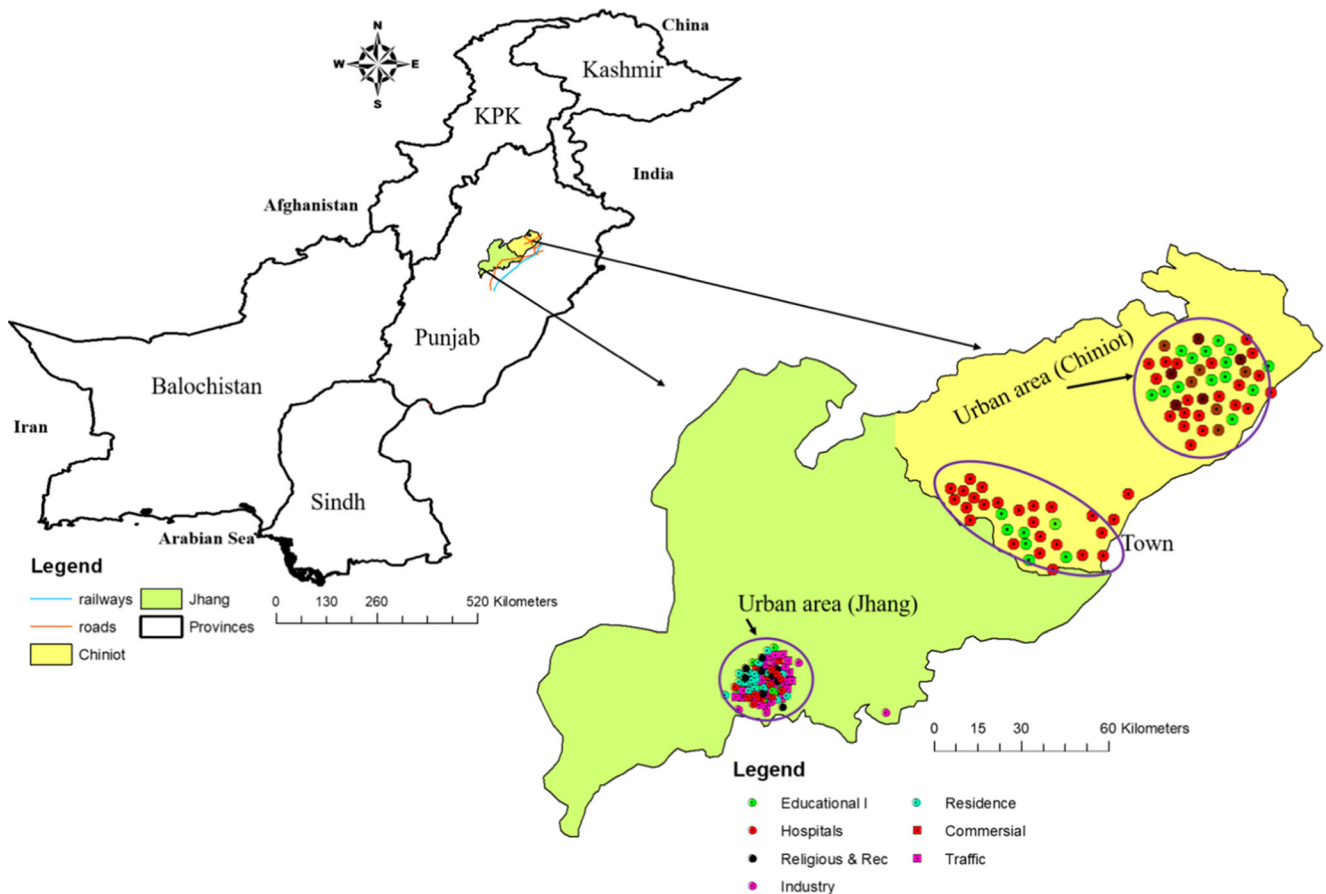

Fig. 1 Sampling locations of Jhang (green) and Chiniot (yellow) urban areas

intersections [17], commercial places [13], educational institutes [12], hospitals [10], residential areas [10], religious and recreational areas [10], and industrial areas [7]) (Fig. 1). The measurement and evaluation of noise levels were performed in compliance with the national legislation of the Pakistan Environmental Protection Agency (Pak-EPA) (Baqar et al. 2018). Noise levels were measured by placing SLM at a tripod at the level of 1.7 m from the level of the pavement and a distance of 3 m from the noise reflecting surface. The intensity of noise was measured in the afternoon one by one at selected areas for continuous 15 min per reading per location (near the receivers) by using SLM. The sound level was measured as A-weighting using SLM model TES-1351B class 2 with a frequency range of 20–8000 Hz and an accuracy of ±1.0 dB (94 dB at 1 kHz). The SLM was calibrated by the internal oscillator at the rate of 1-kHz sine wave general (94 dB) (Farooqi et al. 2020a).

Traffic density measurement

Traffic density was measured as the number of vehicles/h that occupied a segment of a road (Farooqi et al. 2020a). The traffic density was calculated as number of vehicles/h by simple calculation as described by Paunovic et al. (2013) in which the number of vehicles was counted for 15 min at each location simultaneously with noise level recordings.

Questionnaire-based survey

A questionnaire-based survey study was also conducted from the sampling locations of both cities to evaluate the nonauditory human health impacts of noise levels. Further, to get a better perception of noise impacts on human health, a questionnaire was filled by four age groups (≤20, ≤40, ≤60, ≤80 years) and their response was recorded in the form of "agree," "disagree," and "no comments." In addition to basic questions of the health effects of noise, respondents were also asked about the time of the day (morning, evening, afternoon, do not know) when there might be maximum noise levels they experienced.

Statistical analysis

The collected data was analyzed as descriptive statistics. Pearson's correlation analysis was performed to determine the correlation between traffic density and noise levels. Moreover, Pearson's product-moment correlation was performed to determine the effect of age and sex on nonauditory health on the residents due to noise, and between the nonauditory health effects. ArcGIS software (version 10.4.1) was used to produce the maps and categorization of noise levels and traffic densities in the study areas.

Results

Noise levels in Chiniot and Jhang

The descriptive statistics of noise levels and relevant traffic density of various places of Jhang and Chiniot are presented in Table 2. The maximum noise level (LA_{max} = 103 dB with LA_{ave} = 88 dB) was recorded at educational institutes followed by traffic intersections (LA_{max} = 102 dB with LA_{ave} = 86 dB) in Jhang whereas in Chiniot maximum noise level (LA_{max} = 120 dB with LA_{ave} = 89 dB) at commercial places followed by traffic intersections (LA_{max} = 115 dB with LA_{ave} = 93 dB). About 95% (74 out of 78) of the sampling locations in Chiniot and 82% (84 out of 103) locations in Jhang showed noise levels exceeding the permissible limits set by the National Environmental Quality Standards (NEQS), Pakistan.

Category-based noise levels in Chiniot and Jhang

In the case of Chiniot, the maximum noise level within educational institutes was recorded at Bright Star Public Model School (LA_{max} = 93 dB), while the minimum was found at Govt. Islah High School (LA_{min} = 73 dB) with traffic densities of 2586 and 1487 vehicles/h, respectively. In Jhang, the maximum noise level within educational institutes was recorded at Saifia Polytechnic Institute (LA_{max} = 103 dB), while the minimum was recorded at Govt. Model High School (LA_{min} = 74 dB) with traffic densities of 2539 and 2324 vehicles/h, respectively (Table 1S). In hospitals of Chiniot, the maximum noise level was recorded at Pakistan Anti Goiter & Patients Welfare Services (LA_{max} = 99 dB), while the minimum was found at DHQ Hospital (LA_{min} = 78 dB) with traffic densities of 3127 and 2453 vehicles/h, respectively. In Jhang, the maximum noise level within hospitals was recorded at District TB Hospital (LA_{max} = 89 dB), while the minimum was found at Shifa Medical Centre (LA_{min} = 46 dB) with traffic densities of 1294 and 1493 vehicles/h, respectively (Table 1S).

The maximum noise level within commercial areas in Chiniot was recorded at two places, i.e., Azeem Ice Bar and Lucky Mall (LA_{max} = 120 dB), while the minimum was found at NADRA office (LA_{min} = 70 dB) with traffic densities of 4201, 3872, and 1724 vehicles/h, respectively. The maximum noise level within commercial areas of Jhang was recorded at Sabz Mandi (LA_{max} = 89 dB), while the minimum was recorded at Chambeli Market (LA_{min} = 78 dB) with traffic densities of 3497 and 3138 vehicles/h, respectively (Table 2S). In industrial areas of Chiniot, the maximum noise level was recorded at Kashmir Wood Industries (Pvt.) Ltd. (LA_{max} = 98 dB), while the minimum was found at Janjua Agro Industry (LA_{min} = 78 dB) with traffic densities of 3023 and 3044 vehicles/h, respectively. The maximum noise level within industrial areas of Jhang was recorded at Hafiz Rice Mills (LA_{max} = 98 dB), while the

Table 2 Descriptive statistics of short-term road traffic noise and traffic density at selected areas of Jhang and Chiniot

Cities	Descriptive statistics	Noise pollution							Traffic density						
		CP	TI	RR	HP	RA	IA	EI	CP	TI	RR	HP	RA	IA	EI
Jhang	N	6	34	9	10	18	8	18	6	34	9	10	18	8	18
	Mean (LA_{ave})	85	86	60	64	70	85	88	3507	2899	1873	1877	2314	2068	2222
	Median	86	89	62	61	74	83	89	3386	3025	1987	1494	2473	1825	2348
	Minimum (LA_{min})	78	59	39	46	49	74	74	3138	1799	293	1293	1464	1587	1426
	Maximum (LA_{max})	89	102	78	89	89	98	103	4294	3739	2894	3398	3104	3402	2585
	SD	3.8	11	13.5	15.2	12.8	8.0	7.8	420.4	494.4	854.3	779.7	565.7	609.7	341.8
Chiniot	N	13	17	9	10	10	7	12	13	17	9	10	10	7	12
	Mean (LA_{ave})	89	93	80	89	88	86	83	2546	2949	2225	2769	1786	3228	2019
	Median	80	100	80	89	89	84	83	2236	3103	2403	2714	1587	3042	2090
	Minimum (LA_{min})	70	70	60	78	73	78	73	1335	1492	1458	2453	1053	2705	1487
	Maximum (LA_{max})	120	115	95	99	103	98	93	4201	4032	3391	3127	2521	4241	2586
	SD	18.28	13.8	12.3	7.3	9.4	7.2	6.3	928.3	715.1	690.5	233.6	480.4	503.9	360.1
Permissible limit (dB)		70*		55*, 45**			75*, 70**	50*, 45**							

CP, commercial places; *TI*, traffic intersections; *RR*, religious and recreational places; *HP*, hospitals; *RA*, residential areas; *IA*, industrial areas; *EI*, educational institutes. *NEQS-Pak; **WHO

minimum was found at Fawad Ghee Industries (LA_{min} = 74 dB) with traffic densities of 3402 and 1587 vehicles/h, respectively (Table 2S).

The maximum noise level at traffic intersections in Chiniot was recorded at Chowk Shaheed (LA_{max} = 115 dB) while the minimum was found at two sites, i.e., Riaz Shah Road and Tibba Kamangran Road (LA_{min} = 70 dB) with traffic densities of 3603, 2042, and 1830 vehicles/h, respectively. The maximum noise levels in Jhang were recorded at Khokha Chowk (LA_{max} = 102 dB) while the minimum was recorded at Chiniot Road (LA_{min} = 59 dB) with traffic densities of 3406 and 3124 vehicles/h, respectively (Table 3S).

The maximum noise level within residential areas in Chiniot was recorded in Satellite Town (LA_{max} = 103 dB) while the minimum was noticed in Mohallah Kamangran (LA_{min} = 73 dB) with traffic densities of 1643 and 1531 vehicles/h, respectively. In Jhang, the maximum noise level within residential areas was recorded at two sites, i.e., Bhabhrana Mohallah and Sultan Wala Mohallah (LA_{max} = 89 dB), while the minimum at Officer Colony (LA_{min} = 49 dB) with traffic densities of 2683, 3104, and 1464 vehicles/h, respectively (Table 4S). In religious and recreational areas of Chiniot, the maximum noise level was recorded at Saeen Sukh Shrine (LA_{max} = 95 dB) while the minimum was found at Chiniot Golf Club (LA_{min} = 60 dB) with traffic densities of 3391 and 1458 vehicles/h, respectively. In Jhang, the maximum noise level was recorded at Masjid Haq Nawaz Shaheed (LA_{max} = 78 dB) while the minimum was measured at

Nawaz Shareef Park (LA_{min} = 39 dB) with traffic densities of 2553 and 1864 vehicles/h, respectively (Table 4S).

Figure 2 describes noise intensity at each main location of Chiniot and Jhang urban areas. Industrial areas of both cities showed noise intensity in the range LA_{eq15} = 80–100 dB; however, few places showed noise level under the permissible limit (75 dB) set by NEQS-Pak. Traffic intersections of both cities showed noise intensities of $LA_{eq15} \leq 80$, LA_{eq15} = 80–100, and $LA_{eq15} \geq 100$ dB (Fig. 2); only three places in Jhang and two places in Chiniot have noise levels within the permissible limit of 70 dB (Table S3). The commercial area of Chiniot showed noise levels of $LA_{eq15} \leq 80$, LA_{eq15} = 80–100, and $LA_{eq15} \geq 100$ dB whereas Jhang showed noise within LA_{eq15} = 80–100 and $LA_{eq15} \geq 100$ dB. The educational institutes, hospitals, residential, religious, and recreational areas of both cities had noise levels within LA_{eq15} = 80–100 and $LA_{eq15} \geq 100$ dB; however, few samples in the residential area of Chiniot showed noise level $LA_{eq15} \geq 100$ dB.

Relation between noise levels and traffic density (T_f)

Linear regression analyses were performed to determine the effect of traffic density on noise levels. Results revealed that traffic density is directly related to noise levels; however, the relation was weak at Jhang (R^2 = 0.31; Fig. 3a) compared to Chiniot (R^2 = 0.48; Fig. 3c). The relationship of traffic density and noise levels varied with receiving community and showed a spatial variability. The regression analysis revealed strong linear relation between traffic density and noise levels at hospitals (R^2 = 0.79) and residential areas (R^2 = 0.77), whereas
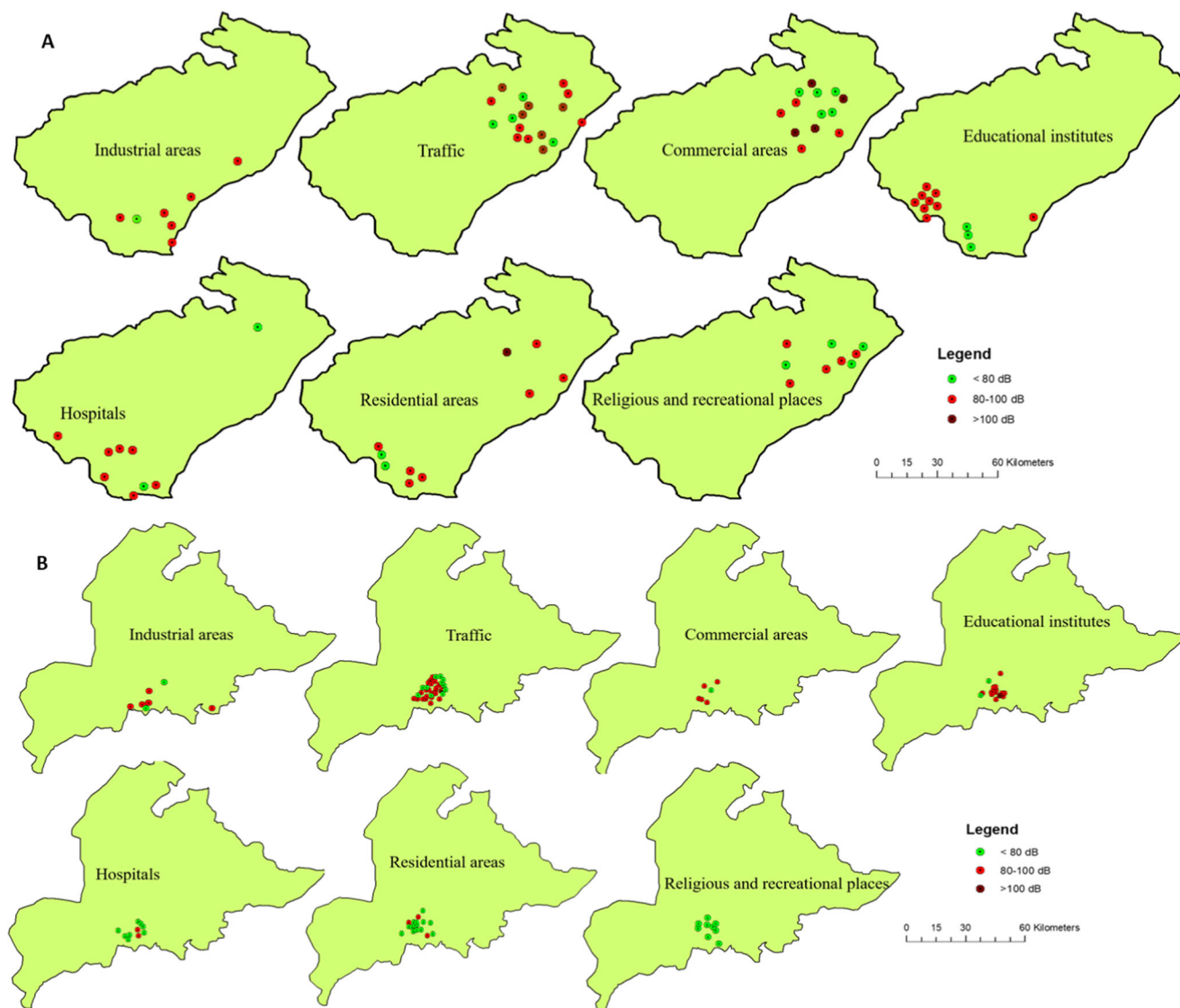
Fig. 2 Classification of short-term urban noise levels (LA$_{eq15}$) at famous locations of **a** Chiniot and **b** Jhang

weak at industrial areas ($R^2 = 0.44$), religious and recreational areas ($R^2 = 0.32$), and commercial places ($R^2 = 0.17$) in Jhang (Fig. 3b). Similarly, strong linear relation between traffic density and noise levels was found at commercial places ($R^2 = 0.85$), traffic intersections ($R^2 = 0.77$), religious and recreational areas ($R^2 = 0.61$), hospitals ($R^2 = 0.53$), and educational institutions ($R^2 = 0.50$) in Chiniot (Fig. 3d).

Survey-based results

In the questionnaire-based survey, noise-related human health effects like annoyance, depression, dizziness, headache, hypertension, hearing loss, physiological stress, sleeplessness, and tinnitus were studied in both Jhang and Chiniot cities. The respondents in this study were residents of both cities comprised of four age groups ($\leq$20, $\leq$40, $\leq$60, $\leq$80 years).

They asked to fill the answer against each question in either of three forms (yes, no, no comment). The survey study revealed that the respondents living in Jhang experienced these diseases on exposure to environmental noise in the following increasing order: sleeplessness (81%) > hypertension (71%) > tinnitus (70%) > headache (67%) > physiological stress (65%) > dizziness (61%) > annoyance (53%) $\geq$ hearing loss (53%) > depression (45%) (Table 3), whereas residents of Chiniot suffered from these diseases on exposure to environmental noise in the following increasing order: sleeplessness (84%) > hypertension (70%) > physiological stress (65%) $\geq$ dizziness (65%) > headache (64%) > tinnitus (62%) > hearing loss (56%) > annoyance (51%) > depression (47%) (Table 3).

Table 4 displays Pearson's product-moment correlation (*r*) between age, sex, and noise-borne nonauditory effects assembled from both studied areas (Jhang and Chiniot). The age
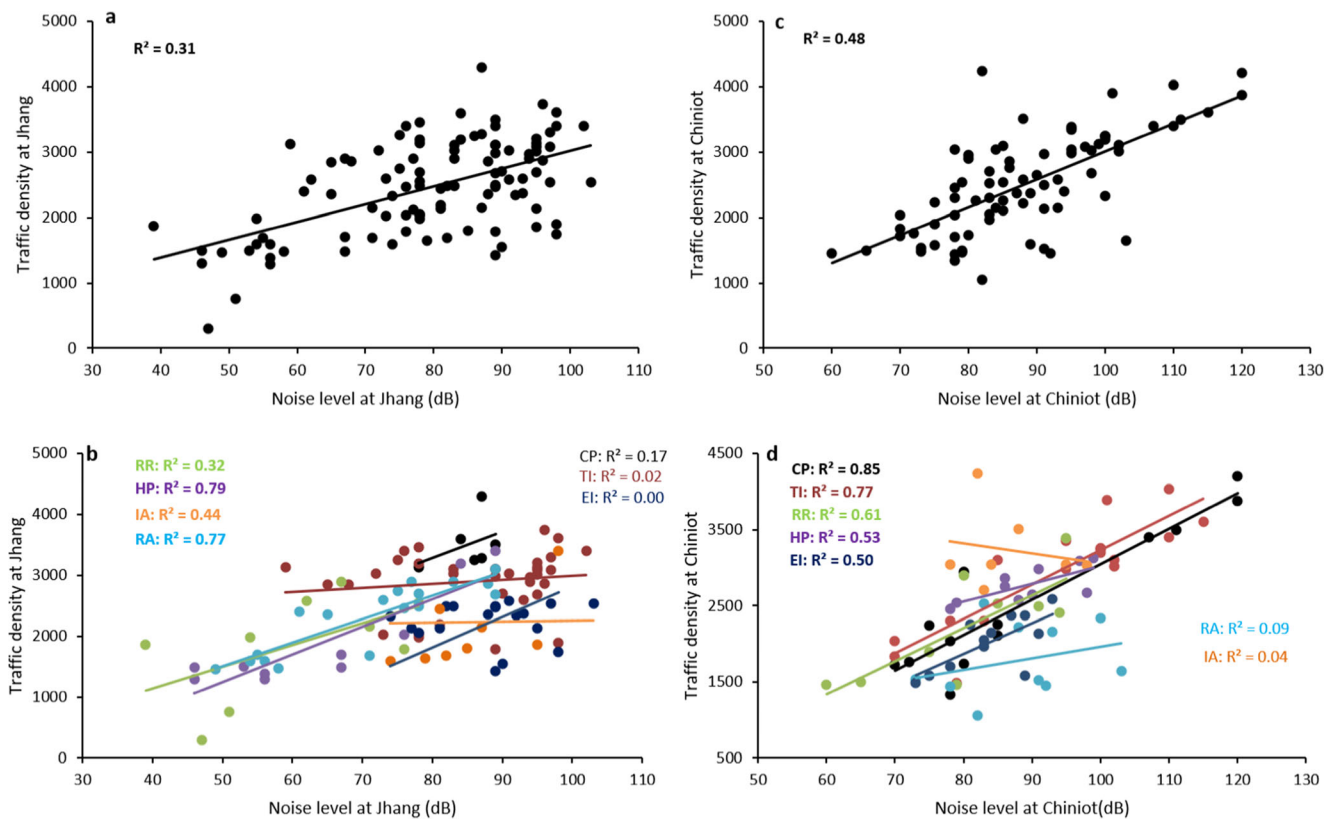
Fig. 3 Regression analysis between short-term noise levels (LA$_{eq15}$) and traffic density in all studied areas of Jhang (**a**) ($n = 103$) and Chiniot (**c**) ($n = 78$), while spatial variability in noise and traffic density at individual source, viz., CP, commercial places ($n = 7$ vs. 13); TI, traffic intersections ($n = 34$ vs. 17); RR, religious and recreational places ($n = 9$ vs. 9); HP, hospitals ($n = 10$ vs. 10); RA, residential areas ($n = 18$ vs. 10); IA, industrial areas ($n = 8$ vs. 7); EI, educational institutes ($n = 18$ vs. 12) of Jhang (**b**) and Chiniot (**d**)

shows a variable response to noise-borne nonauditory health effects at both areas. Age caused significant positive effects on headache ($r = 0.27$, $p < 0.01$) in the residents of Jhang, while headache ($r = 0.58$, $p < 0.01$), depression ($r = 0.28$, $p < 0.01$), hypertension ($r = 0.46$, $p < 0.01$), and physiological stress ($r = 0.34$, $p < 0.01$) in the residents of Chiniot. A negative correlation of sex was found with depression ($r = -0.26$, $p < 0.01$) and hearing loss ($r = -0.25$, $p < 0.05$) while positive with physiological stress ($r = 0.20$, $p < 0.05$). The correlation results revealed that depression caused dizziness ($r = 0.31$–0.38, $p < 0.01$) and headache ($r = 0.36$–0.76, $p < 0.01$) in the residents of Jhang and Chiniot.

The respondents of four age groups were interviewed about the specific times (morning, afternoon, evening, do not know) when they are exposed to maximum level of noise (Table 5). Out of 400 respondents in Jhang, 195 people (48%) responded that they were exposed to maximum noise at afternoon timings. This might be due to the high traffic at school-off timing; 104 (26%) said that they were exposed to high noise at morning time, and 67 people (17%) told that they were exposed to maximum noise at evening timings while 34 people (9%) gave no response. A similar response was obtained in Chiniot where, out of 400 respondents, 223 respondents (56%) were exposed to maximum noise level at afternoon timings. It was

attributed to the high traffic due to school-off timing; 92 respondents (23%) told that they were exposed to high noise at morning time and 54 (14%) told at evening timings while 31 people (7%) gave no response. According to the above results, the citizens of both the cities were exposed to maximum urban noise levels during the afternoon time in the order afternoon > morning > evening.

Discussion

Urban noise levels and pollution are emerging threats to developed and underdeveloped countries; therefore, it is obvious to collect baseline data for effective management of expanding urbanization. Here, in this study, we have tried to determine noise intensity at various gathering places of Jhang and Chiniot urban areas. In both the study areas, we found that most of the sites exceeded the SPL limits prescribed by the NEQS-Pak and WHO (Table 2). For instance, in commercial areas of Jhang and Chiniot, we found noise levels LA$_{max}$ = 89 and 120 dB, respectively, whereas LA$_{max}$ = 102 and 115 dB, respectively, at traffic intersections against the permissible limit of 70 dB; at religious and recreational areas, we found noise levels LA$_{max}$ = 78 and 95 dB, respectively, whereas

Table 3 Impacts of urban noise on citizen's health in Jhang and Chiniot (survey-based response of respondents)

Health impacts	Age group (years) of interviewed citizens of Jhang ($n = 100$)											
	≤20 Yes (%)	≤40	≤60	≤80	≤20 No (%)	≤40	≤60	≤80	≤20 No comment (%)	≤40	≤60	≤80
Annoyance	21	13	10	9	11	14	7	4	4	3	3	1
Depression	2	22	12	9	13	11	10	4	8	6	3	0
Dizziness	1	19	16	25	6	5	8	7	4	3	4	2
Headache	6	19	9	33	13	8	4	4	3	0	0	1
Hypertension	3	15	33	20	8	4	8	2	3	1	1	2
Hearing loss	0	10	14	29	0	8	12	6	11	1	7	2
Phys. stress	3	16	32	14	3	9	12	1	4	3	2	1
Sleeplessness	8	21	32	20	3	2	4	5	3	0	1	1
Tinnitus	0	13	34	23	4	9	10	2	3	2	0	0
	Age group (years) of interviewed citizens of Chiniot ($n = 100$)											
Annoyance	24	8	8	11	12	15	9	4	3	2	3	1
Depression	0	21	15	11	17	13	15	5	0	2	1	0
Dizziness	0	24	17	24	4	7	8	9	6	0	1	0
Headache	4	21	14	25	15	11	2	2	0	0	0	6
Hypertension	1	19	22	28	15	5	2	2	1	2	1	2
Hearing loss	0	9	13	34	2	10	7	5	4	5	10	1
Phys. stress	0	14	35	16	6	11	12	3	1	0	0	2
Sleeplessness	11	23	27	23	1	2	5	5	0	1	0	2
Tinnitus	0	11	22	29	5	5	12	5	5	3	0	3

Phys. stress, physiological stress

LA_{max} = 89 and 99 dB, respectively, at hospitals against the permissible limit of 55 dB and 45 dB set by NEQS-Pak and WHO, respectively. The noise level LA_{max} = 89 and 103 dB, respectively, observed at residential areas against the permissible limit of 65 dB, while LA_{max} = 98 and 98 dB, respectively, at industrial areas of both cities against the permissible limit of 75 dB, 70 dB, and 65 dB set by NEQS-Pak, US EPA, and WHO, respectively. The educational institutes had noise levels LA_{max} = 103 and 91 dB, respectively, against the permissible limits of 50 dB and 45 dB set by NEQS-Pak and WHO, respectively. These findings confirmed that both cities have noise levels (LA_{max}) higher than their respective permissible limits of NEQS-Pak and WHO. Our study is corroborating the findings of Basner and McGuire (2018), who reported that the LA_{max} should be considered for standard comparison when a short-term, single-event, or acute noise was measured.

A strong association between noise level and traffic density has been observed (Fig. 3). This outcome remained consistent in all the categorized areas included in the study and in line with previous findings (Doygun et al. 2016; Purwaningsih et al. 2018). The high traffic density is responsible for high noise pollution (Khan et al. 2018), whereas urban noise is significantly decreased in low traffic areas (Tezel et al. 2019). The present study also confirmed the association between noise and traffic. In the study, the traffic density is positively correlated with noise levels in both cities; however, a strong correlation existed in Chiniot. This consistency is due to the association between noise and different traffic-related noise types such as horns (Muralidharan et al. 2018; Alsina-Pagès et al. 2019), honking (Vijay et al. 2018; Aditya and Chowdary 2020), and engine ignition sounds (Little, 2018; Manea et al., 2017). It might be due to the heavy traffic (dumpers) which transported rocks and crushed stones from Chiniot to all over the country. These dumpers are not usually seen in Jhang. Another reason is the central position of Chiniot, which facilitates the movement of heavy traffic to Lahore, Faisalabad, Sargodha, and Jhang. Chiniot City is the hub of small industry, stone crushing industry, and wood artwork; therefore, many people visit this city on a frequent basis for business purposes which increases traffic frequency and thus high noise levels. The industries are a significant source of noise levels, which are increased with an increase in industrial processes (Deb et al. 2018). The high level of noise in Chiniot is due to working of small industry, and our results revealed that a negative correlation (R^2 = 0.04) existed between noise level and traffic frequency in the industrial setup of Chiniot (Fig. 3d), which conferred that traffic is not the source of the noise; rather, industrial operations might be the possible reason. The dense population per unit area in the city (Table 1) is also the reason behind high noise. The

Table 4 Pearson's product-moment correlation coefficients (*r*) for noise-related and health variables of Jhang and Chiniot

	Age	Sex	ANN	DEP	DIZ	HED	HYP	HEL	PHS	SLL	TIN
Jhang (*n* = 100)											
Age	1.00										
Sex	0.19*	1.00									
Annoyance (ANN)	0.00	−0.12	1.00								
Depression (DEP)	−0.06	−0.26**	−0.03	1.00							
Dizziness (DIZ)	−0.02	0.08	0.17	0.38**	1.00						
Headache (HED)	0.27**	−0.02	0.20	0.36**	0.22	1.00					
Hypertension (HYP)	0.19	0.13	0.08	0.14	0.14	−0.03	1.00				
Hearing loss (HEL)	−0.28**	−0.03	0.17	−0.21	0.02	−0.29*	−0.26*	1.00			
Physiological stress (PHS)	−0.02	0.15	0.31**	−0.13	0.37**	−0.10	0.28**	0.04	1.00		
Sleeplessness (SLL)	−0.10	−0.10	0.12	0.03	−0.01	0.06	0.39**	−0.22*	0.16	1.00	
Tinnitus (TIN)	0.10	0.04	0.25*	−0.28*	−0.04	−0.12	0.17	0.11	0.43**	0.10	1.00
Chiniot (*n* = 100)											
Age	1.00										
Sex	0.19*	1.00									
Annoyance (ANN)	0.02	−0.02	1.00								
Depression (DEP)	0.28**	−0.14	−0.30**	1.00							
Dizziness (DIZ)	−0.18	−0.02	−0.24*	0.31**	1.00						
Headache (HED)	0.58**	0.06	−0.25*	0.76**	−0.22*	1.00					
Hypertension (HYP)	0.46**	0.08	−0.05	0.38**	−0.27**	0.37**	1.00				
Hearing loss (HEL)	−0.05	−0.25*	0.18	−0.38**	0.00	−0.17	−0.43**	1.00			
Physiological stress (PHS)	0.34**	0.20*	0.09	0.17	0.12	0.23	0.35**	−0.08	1.00		
Sleeplessness (SLL)	−0.05	−0.11	−0.33**	0.11	0.09	0.30**	−0.06	−0.20	0.05	1.00	
Tinnitus (TIN)	−0.00	0.10	0.07	0.13	0.49**	−0.45**	−0.10	−0.34**	0.09	0.16	1.00

*Correlation is significant at the $p < 0.05$ level (2-tailed)

**Correlation is significant at the $p < 0.01$ level (2-tailed)

government should take stringent action to control the population growth rate in both cities, ensure maintenance of vehicles, and ban pressure horns in urban areas. Based on the noise level readings of every area category, we divided them into equal intervals (LA_{eq15} = 40–50, LA_{eq15} = 51–60, LA_{eq15} = 61–70, LA_{eq15} = 71–80, LA_{eq15} = 81–90, and $LA_{eq15} \geq$ 90). Only 5 areas ($n = 1$ residential and $n = 2$ in both hospitals and religious and recreational areas in Jhang) were lying in LA_{eq15} = 40–50 dB category, and most of the areas ($n = 25$) are lying in above LA_{eq15} = 90 dB category. An even worse condition was seen in Chiniot where no site had noise levels LA_{eq15} = 40–50 dB while only 1 site lied in LA_{eq15} = 51–60 and above half ($n = 32$) were lying in areas with more than LA_{eq15} = 90 dB noise levels (Table 6).

The nonauditory impact of noise levels on public health is obvious. Survey study revealed that all the respondents in Jhang suffered a higher level of annoyance, headache, hypertension, and tinnitus than residents of Chiniot due to noise; however, depression, dizziness, hearing loss, physiological stress, and sleeplessness were higher in residents of Chiniot than Jhang (Table 3). Several previous studies indicated

different diseases due to noise, for example, people living in noisy city areas are more depressed (Zijlema et al. 2016; He et al. 2019; Díaz et al. 2020) and face anxiety (Afarinesh et al. 2018; Díaz et al. 2020), headache (Yadav and Bilas 2017; Nazneen et al. 2020), increased heartbeat rate (Islam et al. 2016; Nassur et al. 2019), annoyance (Paiva et al. 2019), sleeplessness (Farooqi et al. 2020a), hypertension (Tonne et al. 2016), and psychological stress (Palma et al. 2019; Yarar et al. 2019). This study might have practical significance, as the short-term, single-event, or acute noise has a strong impact on the overall performance of humans and sleep disturbance and can increase blood pressure according to Basner and McGuire (2018). Pearson's product-moment correlation revealed that age had positive impacts on noise-borne nonauditory health effects in humans; especially, headache, depression, hypertension, and physiological stress are directly related to age; however, hearing loss due to noise is more common in children (Table 4). Moreover, noise-borne nonauditory health effects are found in both males and females indicating these effects are independent of gender. Pearson's product-moment correlation results inferred spatial impacts

Table 5 Citizen perceptions about the time of the day when they are exposed to maximum noise levels in Jhang and Chiniot (survey-based response of respondents)

Age groups	People perceptions in Jhang				People perceptions in Chiniot			
	Morning	Afternoon	Evening	No comment	Morning	Afternoon	Evening	No comment
≤20	31	48	15	06	34	45	13	08
≤40	25	40	20	15	21	51	19	09
≤60	35	49	11	05	24	61	13	02
≤80	13	58	21	08	13	66	09	12

of noise-borne nonauditory health effects on the residents of both areas. Our presented results are in line with some of the previous studies conducted in other cities and geographical zones of the world (Table 7), as multiple studies have described the negative impact of noise levels on the nearby community, citizens, patients, and students in the study areas. These results also indicate that there is a significant relationship between the traffic density and the urban noise levels.

Conclusion and recommendations

Traffic noise from a city street can affect the quality of life in noise-sensitive locations. This study revealed that road traffic is the main source of short-term noise (15-min continuous exposure to noise source) in both studied cities; however, the impact was higher in Chiniot (>95%

sampling locations with noise levels ranged from LA_{eq15} = 60–120 dB with LA_{max} = 120 dB) than Jhang (>82% sampling locations with noise levels ranged from LA_{eq15} = 39–103 dB with LA_{max} = 103 dB) exceeding the permissible limits set by NEQS-Pak. The traffic density is directly proportional to noise levels (R^2 = 0.50–0.85 in Chiniot while R^2 = 0.17–0.79 in Jhang). The survey-based results conferred the health impacts of noise levels on residents of both cities.

Keeping in view the psychological and physiological health effects of urban traffic noise, reduction of exposure to noise is an important public health measure. There are several ways to avoid or minimize noise impacts to the maximum extent practicable. The best way to minimize exposure to noise for new objects is to establish the zoning during planning and designing processes with a relevant distance between a source and building, as a recipient of noise. Traffic sources

Table 6 Categories of noise on sampling locations of Jhang and Chiniot

	Categories (LA_{eq15})							Standard limit (dB)	
	≤50	≤60	≤70	≤80	≤90	>90	N	NEQS	WHO
Areas of Jhang									
Commercial areas	-	-	-	1	5	-	34	70	60
Traffic intersections	-	1	2	8	7	16	18	70	
Religious and recreational areas	2	2	2	3	-	-	9	55	45
Hospitals	2	3	2	1	2	-	10	55	45
Residential areas	1	4	2	7	4	-	6	55	45
Industrial areas	-	-	-	2	4	2	18	75	70
Educational areas	-	-	-	3	8	7	8	50	45
Areas of Chiniot									
Commercial areas	-	-	1	6	2	4	13	70	60
Traffic intersections	-	-	2	2	2	11	17	70	
Religious and recreational areas	-	1	-	3	1	3	9	55	45
Hospitals	-	-	-	1	4	5	10	55	45
Residential areas	-	-	-	2	3	5	10	55	45
Industrial areas	-	-	-	1	4	2	7	75	70
Educational areas	-	-	-	3	7	2	12	50	45

Jhang: n = 103, LA_{min} = 39, LA_{max} = 103; Chiniot: n = 78, LA_{min} = 60, LA_{max} = 120

Table 7 Comparative overview of noise pollution monitoring, sources, and associated health risks

City, country	Noise levels (dB)	Source	Health impacts	References
Thessaloniki, Greece	51–77.4	Traffic	Cardiovascular diseases	(Begou et al. 2020)
Barcelona, Spain	35–80	Traffic	Mortality	(Barceló et al. 2016)
São Paulo, Brazil	66–78	Traffic	Annoyance	(Paiva et al. 2019)
New York, USA	≥76	Traffic	Hearing problems	(King et al. 2016)
Tehran, Iran	≥82	Traffic	Harmful effects on the citizens	(Abbaspour et al. 2015)
London, UK	60– ≥65	Traffic	Hypertension, angina, diabetes	(Tonne et al. 2016)
Tokat, Turkey	≥65	Traffic	Nervous frailty, anxiety, dizziness	(Ozer et al. 2009)
Port Harcourt, Nigeria	>97.6	Traffic	Hypertension, hearing disturbance, and high blood pressure	(Ononugbo et al. 2017)
Faisalabad, Pakistan	>101	Traffic	Hypertension, hearing disturbance, headache, sleep disturbances, and dizziness	(Farooqi et al. 2020a)
Jhang, Pakistan Chiniot, Pakistan	103 120	Traffic	Hypertension, headache, sleep disturbances, and dizziness, tinnitus	This study

of noise and noise-sensitive population are normally incompatible unless effective measures are taken to reduce environmental noise. The compatibility depends on the good sound insulation of buildings. Noise from the outer lining of the building must be planned and implemented so that the noise level does not exceed the permissible limits. In environments, where noise effects cannot be readily reduced to a level of less significance by acoustical improvements, noise avoidance and mitigation measures of an existing building may be put in place directly with different noise barriers. As vegetation provides noise attenuation, it can influence noise impact potential for an existing situation of noise. In this case, plant material is economically, esthetically, and psychologically the most suitable for the better acoustical performance of the buildings. Moreover, switching to newer and electric vehicles can reduce the noise levels as they produce less noise as compared to older vehicles. The proposed measures ensure acoustic comfort and health for all the occupants of the buildings. In the end, there should be an incorporation of appropriate preventive measures to minimize the short-term noise impacts, as required under Pak-EPA and WHO recommendations.

Declarations

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