Urban Noise Pollution Assessment and its Non-Auditory Health Effects on the Residents of Chiniot and Jhang, Punjab, Pakistan

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Abstract

Noise pollution is an emerging global problem therefore, it is imperative to determine noise level especially in the urban environment and its implications on human health. The objectives of this study were i) to assess the urban noise pollution and traffic density of Chiniot and Jhang and ii) to determine non-auditory health effects of noise pollution on the residents of both cities. Noise pollution was 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. Noise levels measurements were taken using integrated sound level meter. The urban noise data showed 82% of the sites in Jhang and 95% in Chiniot exceeded the noise limits set by NEQS-Pak and WHO. Moreover, higher intensity of noise pollution (≥ 100 dB) was recorded in Chiniot (17 sites) than in Jhang (1 site). Regression analysis showed 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 at 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. It is concluded that noise pollution is higher in Chiniot due to high traffic density resulted from higher population density and cottage industry. It is recommended that vehicles maintenance, family and urban planning could be effective measures to reduce urban noise pollution.

1. Introduction

The urban noise pollution is recognized as a major problem for the quality of life in metropolitan cities all over the world (Ozer et al. 2009; Fredianelli et al. 2019). As an important environmental element with social and aesthetic attributes, the quality of soundscape is one of the most important factors for environmental perception (Brown and Muhar 2004; Kang 2006; Yong 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; Fedorko et al. 2018; Hahad et al. 2018). Noise pollution is primarily increased due to increase in the number of vehicles on roads, however, there are many factors manipulating the level of traffic noise such as car type and their condition, quality of roads, vehicles density and their physical state, and weather conditions etc. (Wolniewicz and Zagubień 2015). The buildings with low sound insulation have higher level of environmental noise (Ng and Hui 2008; Paiva et al. 2019). It is annoying and disturbing people in their daily life activity (Auger et al. 2018; Javaherian et al. 2018; Mahmud et al. 2019; Farooqi et al. 2020). Normal people can bear the noise up to 80 dB and 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 is 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 SPLeq > 100 dB, which were exceeding the permissible limits of Pakistan Environmental Protection Agency (Farooqi et al. 2017). Urban noise is not only the issue in Pakistan, but also in most parts of the world. In seven major cities of India, majority of sites ranged noise level between 75–90 dB in commercial areas while the limits were 65 dB, 67–93 dB in industrial zone against the limit of 75 dB, 75–85 dB was recorded in residential area against 55 dB, and 60–90 dB range was recorded in silent zones against the limits of 50 dB (Garg et al. 2016). Same patterns of urban noise pollution 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 WHO (Xu et al. 2019). It is also reported that urban noise significantly affect the property prices by 24.4% (Zheng et al. 2020). The main causes of urban noise are the industries and their processes (Liu et al. 2019; Farooqi et al. 2020), and increasing traffic density in the cities due to population increase growth. Traffic vehicles use horns openly which cause noise more than the industrial processes does (Fecht et al. 2016). Increased noise levels due to traffic causes different human health interventions like hypertension (Hahad et al. 2019; Nassiri et al. 2019), headache (migraine) (Ishikawa et al. 2019), tinnitus (Shore and Wu 2019; Wang et al. 2019; Hashim et al. 2019), hearing loss (Kujawa and Liberman 2019; Defourny et al. 2019), sleep disturbances (Brink et al. 2019; Farooqi et al. 2020). According to a report by WHO, 45,000 DALYs (disability-adjusted life year) 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).

In Pakistan, the urban noise is affecting the citizens 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 pollution and traffic density of Chiniot (new civilization) and Jhang (old civilization), ii) survey-based assessment of non-auditory 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 management of noise pollution and its health impacts on residents of targeted cities.

2. Materials And Methods

2.1. Geo and Demo-graphic features of study area

Jhang and Chiniot are the developing cities of Punjab, Pakistan. Chiniot was a tehsil of District Jhang but now it is independent District of Punjab. The Chiniot is densely populated (524.9 persons/km^2) as compared to Jhang (431.9 persons/km^2). According to recent census in 2017, Jhang has 2.74 and Chiniot has 1.36 million populations with the increasing 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 passenger's travel within these cities using motorbikes, cars, and buses, which are the significant factors to produce noise and influence inhabitants. This study compiles the basic data about urban noise pollution, traffic density and its impact on residents of both cities. Figure 1 describes all the sampling locations for urban noise pollution determination of Jhang (green) and Chiniot (yellow) cities.

Table 1
Geo- and Demo-graphic features of Chiniot and Jhang during the study period

Information	Unit	Information of	
		Chiniot	Jhang
Population (2017 Census)	Millions	1.37	2.743
Population Growth Rate	%	1.86	2.04
Rank according to population in Pak.	-	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
Avg. temperature during winter	ºC	9 ± 4	11 ± 4
Humidity	%	68.8 ± 4	65.3 ± 4
Wind speed	$km\ h^{-1}$	7.3 ± 1.9	6.8 ± 1.9

2.2. Measurement of noise levels

Field measurements were taken during September 2019 by sound level meter (SLM) for obtaining data about noise level (L_{aeq}) 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 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 Pak-EPA (Iyer et al. 2017). Noise levels were measured by placing SLM at tripod at the level of 1.7 meters from the level of the pavement, distance of 3 meters from the noise reflecting surface. The intensity of noise was measured in afternoon one by one at selected areas for 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 type 2 with a frequency range of 20–8000 Hz and accuracy of ± 1.0 dB (94 dB @1 kHz). The SLM was calibrated by the internal oscillator at the rate of 1 kHz sine wave general (94 dB) (Farooqi et al. 2020).

2.3. Traffic density measurement

Traffic density was measured as the number of vehicles/h that occupied a segment of a road (Farooqi et al. 2020). 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 minutes at each location simultaneously with noise levels recording.

2.4. Questionnaire based survey

A questionnaire-based survey study was also conducted from the sampling locations of both cities to evaluate the non-auditory human health impacts of noise pollution. Further, to get 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 health effects of noise, respondents were also asked about time of the day (Morning, Evening, After-noon, don't know) when there might be maximum noise pollution.

Statistical analysis

The collected data was analyzed as descriptive statistics. Pearson correlation analysis was performed to determine correlation between traffic density and noise levels. Moreover, Pearson product moment correlation was performed to determine the effect of age and sex on non-auditory health effects on the residents due to noise, and between the non-auditory 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.

3. Results

3.1. Noise levels in Chiniot and Jhang

The descriptive statistics of noise pollution and relevant traffic density of various places of Jhnag and Chiniot are presented in Table 2. The maximum noise level (dB_{max} = 103 with dB_{ave} = 88) was recorded at educational institutes followed by traffic intersections (dB_{max} = 102 with dB_{ave} = 86) in Jhang whereas in Chiniot maximum noise level (dB_{max} = 120 with dB_{ave} = 89) at commercial places followed by traffic intersections (dB_{max} = 115 with dB_{ave} = 93). 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 National Environmental Quality Standards (NEQS), Pakistan.

Table 2
Descriptive statistics of noise pollution 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	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	78	59	39	46	49	74	74	3138	1799	293	1293	1464	1587	1426
	Maximum	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	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	70	70	60	78	73	78	73	1335	1492	1458	2453	1053	2705	1487
	Maximum	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**

3.2. Category based Noise levels in Chiniot and Jhang

In case of Chiniot, maximum noise level within educational institutes was recorded at Bright Star Public Model School (93 dB), while minimum was found at Govt. Islah High School (73 dB) with traffic density of 2586 and 1487 vehicles/h, respectively. In Jhang, maximum noise level within educational institutes was recorded at Saifia Polytechnic Institute (103 dB), while minimum was recorded at Govt. Model High School (74 dB) with traffic density of 2539 and 2324 vehicles/h, respectively (Table 1S). In hospitals of Chiniot, maximum noise level was recorded at Pakistan Anti Goiter & Patients Welfare Services (99 dB), while minimum was found at DHQ hospital (78 dB) with traffic density of 3127 and 2453 vehicles/h, respectively. In Jhang, maximum noise level within hospitals was recorded at District TB hospital (89 dB), while minimum was found at Shifa medical Centre (46 dB) with traffic density 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 (120 dB), while minimum was found at NADRA office (70 dB) with traffic density of 4201, 3872 and 1724 vehicles/h, respectively. The maximum noise level within commercial areas of Jhang was recorded at Sabz Mandi (89 dB), while minimum was recorded at Chambeli Market (78 dB) with traffic density of 3497 and 3138 vehicles/h, respectively (Table 2S). In industrial areas of Chiniot, maximum noise level was recorded at Kashmir Wood Industries (Pvt.) Ltd. (98 dB), while minimum was found at Janjua Agro-Industry (78 dB) with traffic density of 3023 and 3044 vehicles/h, respectively. The maximum noise level within industrial areas of Jhang was recorded at Hafiz Rice mills (98 dB), while minimum was found at Fawad Ghee Industries (74 dB) with traffic density of 3402 and 1587 vehicles/h, respectively (Table 2S).

The maximum noise level at traffic intersections in Chiniot was recorded at Chowk Shaheed (115 dB) while minimum was found at two sites i.e. Riaz Shah Road and Tibba Kamangran Road (70 dB) with traffic density of 3603 and 2042, 1830 vehicles/h, respectively. The maximum noise levels in

Jhang was recorded at Khokha Chowk (102 dB) while minimum was recorded at Chiniot Road (59 dB) with traffic density of 3406 and 3124 vehicles/h, respectively (Table 3S).

The maximum noise level within residential areas in Chiniot was recorded in Satellite Town (103 dB) while minimum was noticed in Mohallah Kamangran (73 dB) with traffic density 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 (89 dB) while minimum at Officer Colony (49 dB) with traffic density of 2683, 3104 and 1464 vehicles/h, respectively (Table 4S). In religious and recreational areas of Chiniot, maximum noise level was recorded at Saeen Sukh Shrine (95 dB) while minimum was found at Chiniot Golf Club (60 dB) with traffic density of 3391 and 1458 vehicles/h, respectively. In Jhang, the maximum noise level was recorded at Masjid Haq Nawaz Shaheed (78 dB) while minimum was measured at Nawaz Shareef Park (39 dB) with traffic density of 2553 and 1864 vehicles/h, respectively (Table 4S).

Figure 3 describes noise intensity at each main location of Chiniot and Jhang urban areas. Industrial areas of both cities showed noise intensity in the range 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 intensity of < 80, 80–100 and > 100 dB (Fig. 3), only three places in Jhang and two places in Chiniot have noise level within permissible limit of 70 dB (Table S3). The commercial area of Chiniot showed nosie level of < 80, 80–100 and > 100 dB whereas Jhang showed noise within 80–100 and > 100 dB. The educational institutes, hospitals, residential, religious, and recreational areas of both cities had noise level within 80–100 and > 100 dB, however, few samples in residential area of Chiniot showed noise level > 100 dB.

3.3. Relation between noise levels and traffic density (T_f)

Linear regression analyses were performed to determine effect of traffic density on noise pollution. Results revealed that traffic density is directly related to noise pollution, however relation was weak at Jhang (R^2 = 0.31; Fig. 2a) compared to Chiniot (R^2 = 0.48; Fig. 2c). The relationship of traffic density and noise pollution varied with receiving community and showed a spatial variability. The regression analysis revealed strong linear relation between traffic density and noise pollution at hospitals (R^2 = 0.79), residential areas (R^2 = 0.77), whereas weak at industrial areas (R^2 = 0.44), religious and recreational areas (R^2 = 0.32), commercial places (R^2 = 0.17) in Jhang (Fig. 2b). Similarly, strong linear relation between traffic density and noise pollution 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. 2d).

3.4. Survey based results

In 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 (≤ 20, ≤ 40, ≤ 60, ≤ 80 years) and asked to fill answer against each question in either of three forms (Yes, No, No comment). Survey study revealed that all the respondents in Jhang suffered higher level of annoyance (53 vs. 51%), headache (67 vs. 64%), hypertension (71 vs. 70%), and tinnitus (70 vs. 62%) than residents of Chiniot due to noise, however, depression (45 vs. 47%), dizziness (61 vs. 65%), hearing loss (53 vs. 56%), physiological stress (65 vs. 65%), and sleeplessness (81 vs. 84%) were higher in residents of Chiniot than Jhang (Table 3). Table 4 displays Pearson product moment correlation (r) between age, sex, and noise-borne non-auditory effects assembled from both studied areas (Jhang and Chiniot). The age shows a variable response to noise-borne non-auditory 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, $P < 0.01$), physiological stress (r = 0.34, $P < 0.01$) in the residents of Chiniot. The negative correlation of sex found with depression (r= -0.26, $P < 0.01$), 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.

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

Health impacts	Age group (years) of interviewed citizens of Jhang (n = 100)											
	≤ 20	≤ 40	≤ 60	≤ 80	≤ 20	≤ 40	≤ 60	≤ 80	≤ 20	≤ 40	≤ 60	≤ 80
	Yes (%)				No (%)				No comment (%)			
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

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

Jhang (n = 100)	**AGE**	**SEX**	**ANN**	**DEP**	**DIZ**	**HED**	**HYP**	**HEL**	**PHS**	**SLL**	**TIN**
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).											

The respondents of four age groups were interviewed about the specific times (morning, afternoon, evening, don't 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. 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 afternoon time with the order afternoon > morning > evening.

Table 5
Citizens perceptions about time of the day, when they are exposed to maximum noise levels in Jhang and Chiniot (survey base 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

4. Discussion

Noise pollution is an emerging threat to developed and under-developed 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 89 and 120 dB noise pollution, respectively and traffic intersections we found 102 and 115 dB against the permissible limit of 70 dB, religious and recreational areas we found 78 and 95 dB and hospitals 89 and 99 dB against the permissible limit of 55 dB and 45 dB set by NEQS-Pak and WHO, respectively. The noise level 89 and 103 dB observed in residential areas against the permissible limit of 65 dB, while 98 dB in 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 level of 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 pollution levels higher than permissible limits of NEQS-Pak and WHO.

A strong association between noise level and traffic density has been observed (Fig. 2). This outcome remained consistent in all the categorized areas included in the study and in line with the 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 association of noise and traffic. In the study, the traffic density is positively correlated with noise pollution in both cities, however, strong correlation existed in Chiniot. This consistency is due to the association between noise and different traffic related noise types like horns (Muralidharan et al. 2018; Alsina-Pagès et al. 2019; Chang 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 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 frequent basis for business purpose which increases traffic frequency and thus high noise pollution. The industries are significant source of noise pollution, which is increased with increase in the industrial processes (Kannan et al. 2017; Deb et al. 2018; Kim et al. 2019). The high level of noise in Chiniot is due to working of small industry and our results revealed that negative correlation (R^2 = 0.04) existed between noise level and traffic frequency in industrial set up of Chiniot (Fig. 2d), which conferred that traffic did not the source of 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. Govt. should take stringent action to control population growth rate in both cities, ensure maintenance of vehicles and ban on pressure horns in urban areas. Based on the noise level readings of every area category, we divided them into equal intervals (40–50, 51–60, 61–70, 71–80, 81–90 and ≥ 90). Only 5 areas (1 residential and 2 both in hospitals and religious and recreational areas in Jhang) were lying in 40–50 dB category and most of the areas (n = 25) lying in above 90 dB category. Even worse condition was seen in Chiniot where no site had noise levels between 40–50 dB while only 1 site lied in between 51–60 and above half (n = 32) were lying in areas with more than 90 dB noise levels (Table 6).

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

Areas of Jhang	**Categories**							**Standard limit (dB)**	
	≤ 50	**≤ 60**	**≤ 70**	**≤ 80**	**≤ 90**	**> 90**	**N**	**NEQS**	**WHO**
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, min = 39, max = 103 **Chiniot**: n = 78, min = 60, max = 120									

Non-auditory impact of noise pollution on public health is obvious. Survey study revealed that all the respondents in Jhang suffered 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 study 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; Diaz et al. 2020), face anxiety (Afarinesh et al. 2018; Diaz et al. 2020), headache (Yadav and Bilas 2017; Nazneen et al. 2020), increased heart beat rate (Islam et al. 2016; Nassur et al. 2019), annoyance (Paiva et al. 2019), sleeplessness (Farooqi et al. 2020), hypertension (Tonne et al. 2016) and psychological stress (Palma et al. 2019; Yarar et al. 2019). The Pearson product moment correlation revealed that age had positive impacts on noise-borne non-auditory 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 non-auditory health effects are found in both males and females indicating these effects are independent to gender. Pearson product moment correlation results inferred spatial impacts of noise-borne non-auditory 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.

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. 2020)
Jhang, Pakistan	103	Traffic	Hypertension, headache, sleep disturbances and dizziness, tinnitus	This study
Chiniot, Pakistan	120			

5. Conclusion And Recommendations

Traffic noise from a city street can affect the quality of life in noise-sensitive locations. This study revealed that traffic and industrial operation are the two main sources of noise in both studied cities, however the impact was higher in Chiniot (> 95% sampling locations) than Jhang (> 82% sampling locations) exceeding the permissible limits set by NEQS-Pak. The traffic density is directly proportional to noise pollution (R^2 = 0.50–0.85 in Chiniot while R^2 = 0.17–0.79 in Jhang). The survey-based results conferred health impacts of noise pollution 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 a noise for new objects is to establish the zoning during planning and designing processes with relevant distance between a source, and building, as a recipient of noise. Traffic sources of noise and noise-sensitive population are normally incompatible unless effective measures are taken to reduce environmental noise. The compatibility depends on a 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 existing situation of noise. In this case, a plant material is economically, aesthetically, and psychologically the most suitable for the better acoustical performance of the buildings. The proposed measures ensure acoustic comfort and health for all the occupants of the buildings. At the end, there should be incorporation of appropriate preventive measures to minimize the noise impacts, as required under Pak-EPA and WHO recommendations.

Declarations

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics approval and consent to participate

This study does not involve any humans or animals during experimentation, so it does not applicable in this study.

Consent for publication

Survey was conducted in local community of both cities and questionnaire was filled with their verbal consent.

Phys. Stress

Physiological stress

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Authors contributions

ZUR, IA, PI: conceptualization, writing - original draft preparation, methodology, investigation; NZ: methodology, investigation; MI, MFS: methodology, resources & analysis; IA, PI: writing- reviewing and editing, resources, supervision.

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Figures

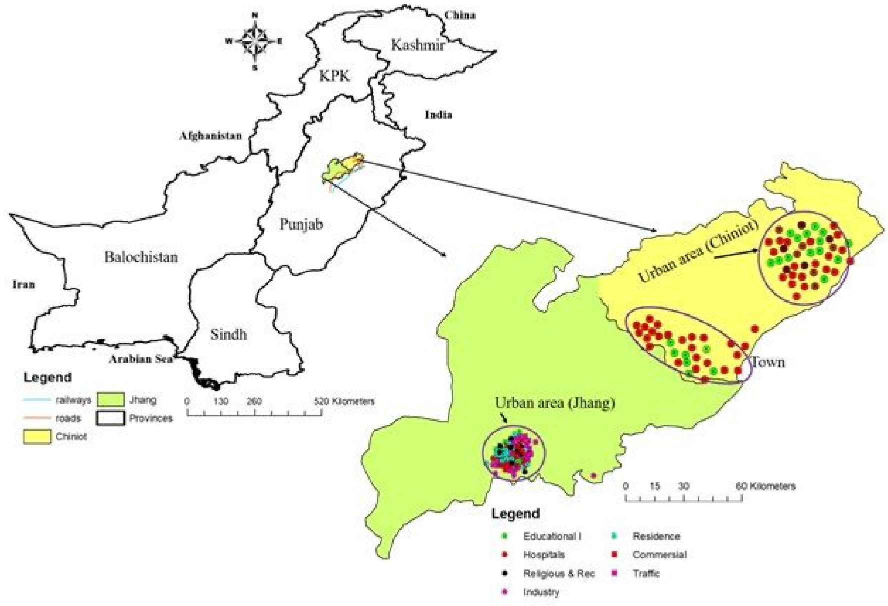

Figure 1

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

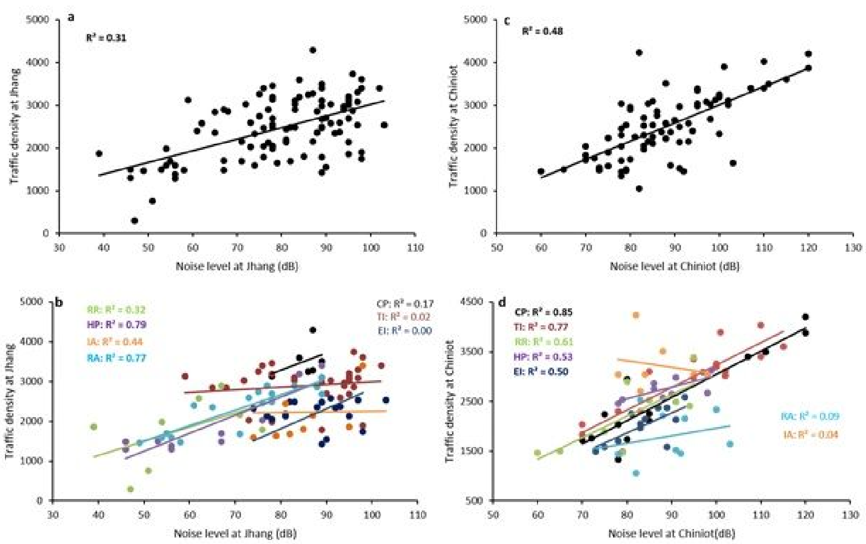

Figure 2

Regression analysis between noise pollution 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).

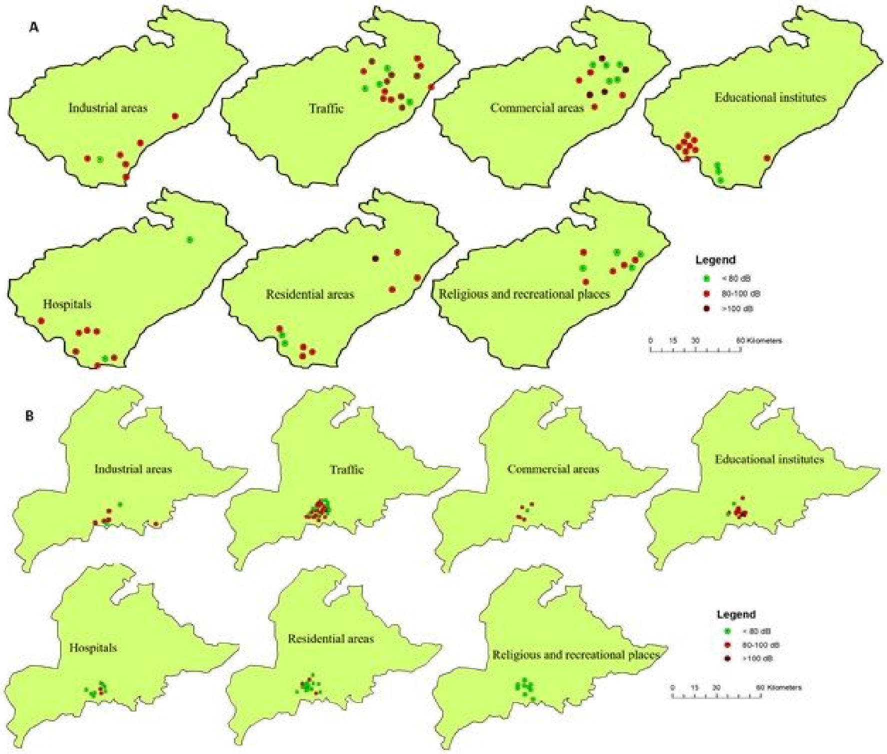

Figure 3

Classification of urban noise pollution of a) Chiniot and b) Jhang famous locations.

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