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Original Research

Effect of Seasonal Variation and Meteorological Parameters on the Environmental Noise Pollution in the Selected Areas of Rawalpindi and Islamabad, Pakistan

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Abstract

Environmental noise is one of the most unpredictable pollutants that adversely affect humans' physical and mental health. In this study, noise levels were recorded from six different locations of Rawalpindi and Islamabad, Pakistan. The purpose was to evaluate the noise levels and corresponding noise intensities with the variation of seasonal and meteorological factors. The noise levels were recorded with a calibrated digital sound level meter, and corresponding sound intensity levels were calculated. Temperature and humidity values were also recorded. Data was recorded for four different time slots, and 84 readings were recorded from each location over seven months. The average noise level recorded from selected locations of 6th road, Pirwadahi, Raja-bazar, Faizabad Rawalpindi, I-9/3 sector Islamabad and Karachi Company were 71.0, 85.5, 83.7, 79.9, 75.7, and 69.5 dB, respectively. These all exceeded the prescribed limits of the National Environmental Quality Standards (NEQS). A trend of increasing noise levels during summer was observed with increasing humidity levels. Significant variation of noise levels was observed diurnally and seasoned wise between winter and summer months. To control and reduce noise pollution from the selected locations, the authorities should take proper countermeasures.

Keywords: humidity effect, noise pollution; seasonal effect, temperature effect

Introduction

Noise pollution is one of the contaminants that disrupts, distracts, and detracts from the regular functioning of life. This pollution is not new; it became more substantial and more problematic with time and the advancement of technology and new developments [1]. When two waves with different frequencies overlap and do not produce a systematic sinusoidal wave but an irregular wave with jerks, a normal sound becomes a noise [2]. Noise pollution is still ignored as a type of pollution in many developed cities in the world [3]. According to the World Health Organization (WHO), noise pollution is the third most hazardous

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environmental pollution in the world [4]. It is a very harmful pollutant because it is not easily recognized. The human ear's sensitivity is automatically adjusted to the ambient level of sound, and high levels of sound go ignored. Therefore, an increase in the noise level damages human health mentally and physically silently. Our hearing is most sensitive in the 2000-5000 Hz frequency range. The threshold frequency of hearing is zero decibels scale (dB). Frequency ranges from 0 to 10 dB are so quiet and almost impossible to hear, while the top end scale level at 150 dB can damage the eardrum of a normal person [5].

Noise pollution makes its origin from anthropogenic activities, significantly the urbanization and the unsustainable growth of transportation [6]. Due to the advancement in technologies and tremendous growth in automobile industries, traffic noise has become a significant and dominating source of noise pollution. Unplanned infrastructure, improper shops and stalls, uncontrolled parking, unawareness, excessive use of loudspeakers and lack of check and balance are also the prominent reasons for the noise pollution in the cities [7].

Numerous medical studies have proved that noise is one of the major sources of physiological stress reactions like increasing blood pressure and increasing heartbeat rate and generating both acute and chronic health effects [8-10]. Noise above 80 dB may increase aggressive behavior and the demand for various drugs and anti-depression pills increases due to the noise related mental health problems [11]. WHO recommends the daytime noise limits of about 55dB as a general health goal for residential areas' outdoor noise level. While outdoor noise level of about 45 dB is recommended at night [12]. Noise pollution is also called a silent pollutant because most people are still unaware of the adverse effects of that pollution [13, 14]. The revised National Environmental Quality Standards (NEQS) of Pakistan for noise level effective from 1st July 2012 are 55 dB for residential area and 65 dB for the commercial area. At the same time, NEQS of noise levels for the industrial area are 75 dB. Sudden noise seems to be more harmful to hearings compared with continuous noise [15].

Noise pollution is one reason to make people nervous and lead them to an unconfident position. It may cause damage to the hearing sense temporarily or permanently. In Dhaka city of Bangladesh, it was reported that habitants' hearing ability gets reduced up to deafness level due to this deadly pollution [16]. The prevention and reduction of environmental pollution have now prominently increased with the urban living standards [17, 18]. In urban ecosystems, there is a great importance of green areas and protected landforms. Green spaces play a vital role as air purifiers and reduce air pollution [19]. Traffic-related air pollution has increased in developing cities contributed by the urban traffic in and around the cities [20]. Air pollution is relatively high in urban roads, which are also open-green areas. It has been reported that the polluted gases in the air are 5-25 times higher in urban areas, while the dust particles are ten times higher in urban areas as compared to the surrounding rural areas in developing cities of Turkey [21-24].

As the number of vehicles involved into urban or suburban traffic is rising rapidly; traffic-related pollution has also started to increase [25-27]. Significant environmental pollution factors in cities include population growth, urbanization, and industrialization [28, 29]. Traffic noise pollution has a strong impact on hearing potential. When an individual has an exposure to loud noise for a long time, it can lead to the hearing impairment which can interrupt normal activities [30]. Hearing loss due to noise is affected by various factors such as exposure period, noise level, age of workers, and workers' physical condition.

In many cases, noise can account for quickened pulse rates, increased blood pressure, and narrow blood vessels. Workers exposed to noise have symptoms of nervousness, sleeplessness, and fatigue. For most effects of noise, there is no cure. However, the prevention of excessive noise exposure is the only way to avoid health damage [31]. According to the research carried out in Sir Ganga Ram Hospital Lahore, Pakistan, about 65% of public transport drivers were exposed to noise-induced hearing loss. About 25 % of drivers had average hearing threshold, and 10% had disabling hearing loss [16, 31].

Seasonal and climatic variations are found to affect noise parameters and also anthropogenic activities. Noise levels were recorded higher during mornings and evenings in Karachi, Pakistan because of the school and office timings. Maximum noise level was found over 101 dB; close to 110 dB, which may cause hearing impairment [32, 33]. It is known that noise propagation and emissions from some sources vary with meteorological conditions, because of change in ground absorptivity. Seasonal variations in emissions and propagation of noise are commonly accounted for in noise surveys. However, in most situations, such effects are minor, short-lived, or localized. Few surveys report seasonal differences as annoyance reactions are higher during warmer periods [34, 35]. While a few other studies did not find seasonal effects on noise levels. It may be stated that noise annoyance varies over the year and is increased by temperature, more sunshine, less precipitation, and reduced wind speeds. However, a concrete relationship of noise levels with the variation of meteorological conditions is not sufficiently established [36].

The noise level is also affected by traffic speed and volume, vehicle type, ground conditions, terrain, sound barriers, atmospheric absorption and meteorological variables, and their spatial and temporal profiles. Atmospheric factors influence becomes particularly critical when noise mitigation has to be done through various techniques, such as noise walls and quiet pavements. Open and green areas play a vital role

in atmospheric noise absorption, thus healthy development of cities. These areas may function as recreation, ecology, and land organization. In addition to the recreation role, they improve the ecological balance inside the city as they remove the dust and harmful gases from the polluted air. The urban air is polluted due to various anthropogenic activities including industrial plants, residential areas and motorized vehicles [37, 38].

According to a model, atmospheric effects can raise sound levels by 10-20 dB at significant distances away from the highway [39]. So, the public should be educated regarding the use of protective ear muffs and plugs. Building facades is one reason to increase the level of noise up to 3 to 4 dB. Green spaces have been proved to have a constructive effect of lowering noise levels [40]. Vegetation barriers also act as noise-reducing method [41, 42].

Keeping in view the noise pollution sources and the hazardous effects on human health; this study was designed to measure noise levels at different twin cities' locations. To determine the seasonal variation, the span of data collection covered seven months to compare wet and dry months. Meteorological effects on noise levels were studied by comparison of data at different times of the day. Presently no sufficient data is available for Rawalpindi and Islamabad with the influence of seasonal variation and metrological parameters, so this study will add to existing knowledge and suggested mitigation measures to formulate a mitigation plan.

Materials and Methods

Study Area

Six different locations were selected for the evaluation of the noise levels in Rawalpindi and Islamabad. Twin cities are ranked in the top 6 populated cities of Pakistan as per the 2017 census official results. Four locations were selected from Rawalpindi, and two locations were chosen from Islamabad. The target areas were selected due to the following factors:

– Commercial areas
– The high traffic flow area
– Industrial area
– Highly congested areas

Location and their coordinates are shown in Table 1. Fig. 1 illustrates the map of the study locations.

Recorded Parameters

Following are the parameters recorded from each location.

a. The atmospheric temperature in degree Celsius
b. Relative humidity in percentage
c. The noise level in that area in dB
d. The intensity level in watt/m^2 was calculated by using the intensity level formula

$$I = \text{Antilog}\,[\,L/10 + \log I0] \quad (1)$$

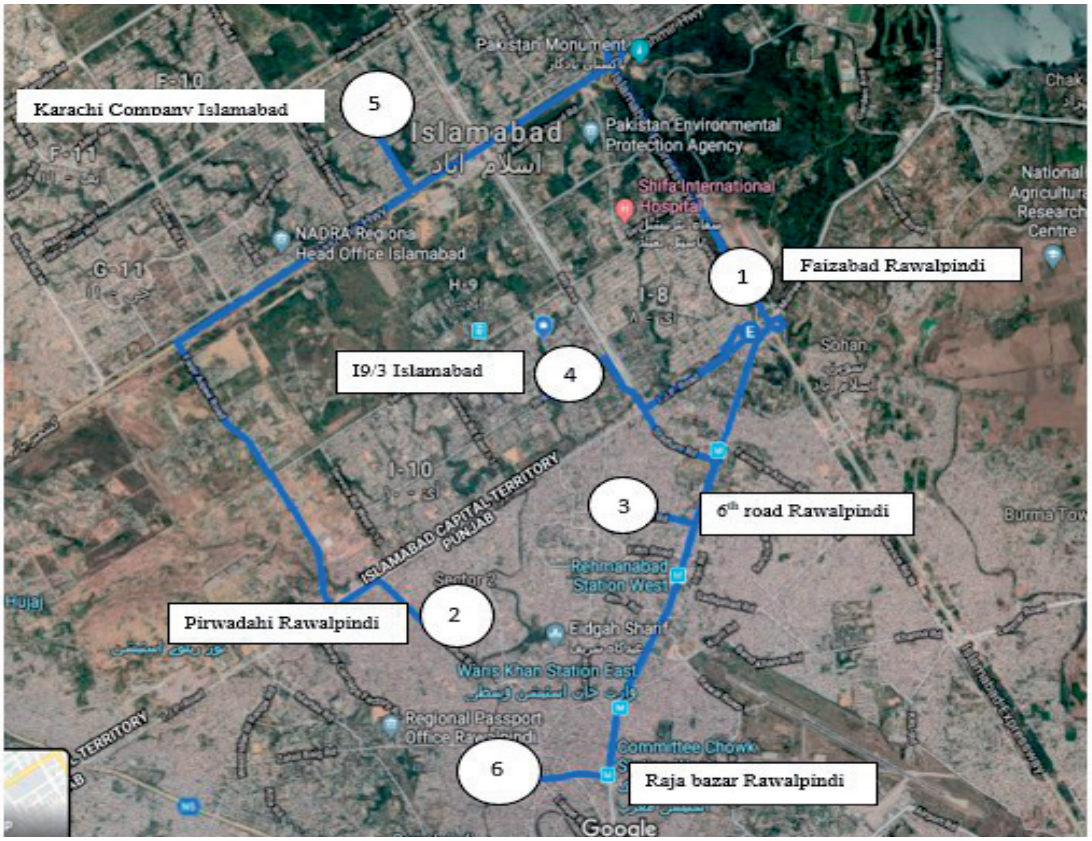

Fig. 1. Map of study area

Table 1. Locations of study area with GPS co-ordinates.

S. No	Selected Locations	Coordinates	
1	Faizabad, Rawalpindi	33.6621° N	73.0834° E
2	Pirwadahi, Rawalpindi	33.6298° N	73.04200° E
3	6th Road, Rawalpindi	33.6431° N	73.0643° E
4	I-9/3, Islamabad	33.6617° N	73.0568° E
5	Karachi Company, Islamabad	33.6888° N	73.0328° E
6	Raja Bazar, Rawalpindi	33.6145° N	73.0555° E

Instrumentation

Sound level meter Model # JK-NM-814 with the capacity of measuring noise from 30 dB to 130 dB, having an accuracy of ±1.5dB was used to measure the noise level. Operation conditions of instrument are relative humidity <99 %, temperature = 0 to 40ºC and response time of noise meter 0.5 to 1 second. Digital temperature and humidity meter was used for recording temperature in ºC and humidity ratio in percentage.

Data Collection Design

Noise level data was recorded from morning 7 am till night 10 pm in four different time slots. From each location, in total, 84 readings were recorded and their mean values were found to obtain a single value. Each measurement was recorded after a regular interval of 10 minutes. Three times data were recorded during each time slot. Overall data were recorded for a seven months' time period from December 2018 to June 2019. Standard deviation was calculated from 84 measurements obtained from each location in such a way to cover the maximum area of specific locations. Data was collected to observe the seasonal and diurnal variations. Hence the measurements were recorded in two phases. The first phase for data collection was starting from December 2018 to February 2019. The temperature range was recorded from 6ºC to 22ºC during the first phase. The second phase of data collection was from March 2019 to June 2019. The temperature range was recorded from 25ºC to 42ºC during the second phase. In order to investigate the diurnal variation, data were recorded in four different time slots of a day from each location. S1 from 7:00 to 8:00 am, S2 from 1:00 to 2:00 pm, S3 from 5:00 to 6:00 pm, and S4 from 9:00 to 10:00 pm, respectively. Analysis of Variance in Excel 2010 did the analysis of data.

Results and Discussion

The data collected in the first phase of the study is presented in Table 2. The temperature range was recorded from 6 to 22ºC. Humidity percentage was recorded to be less than 90% during the first phase, December 2018- February 2019. To investigate the diurnal variation, data were recorded in different time slots of a day from each location. The second phase of data collection started from March to June 2019 as shown in Table 3. The temperature range was recorded from 25 to 42ºC, and humidity percentage was recorded to be less than 90% during the second phase. The variation between average values of recorded noise levels and noise intensity during 1st and 2nd phases is shown in Figs 2 and 3. Table 4 represents the average values of noise levels, their corresponding intensity levels, maximum and minimum noise levels for comprehensive analysis.

Measurement of noise level data during different time periods of the day shows a trend of variation in noise levels. The variation is found to be statistically significant during different time slots of the same location and various locations. The only exception was the location of Karachi Company, where noise level data during summer months did not show significant variation. It might be due to similar business activities all the time at this location. However, the same location showed substantial diurnal variation in data during the winter months. In order to summarize all the recorded data, average measurements were calculated to represent the noise levels and their corresponding sound intensity level during the seven months of the study period. Table 4 describes the average value of noise levels, their corresponding intensity levels, maximum and minimum noise levels for comprehensive analysis. It was observed that the noise level of location Pirwadahi, Rawalpindi was 20 dB above the prescribed limit of 65 dB, with a calculated intensity level of 3.54×10^{-4} w/m^2. While the highest noise recorded was up to 96.4 dB, which exceeded 31.4 dB from the standard limit. Location Raja bazar is a commercial zone of Rawalpindi, so its permissible noise limit assigned by NEQS was also 65 dB. The noise level recorded at this location was exceeding 19 dB from its standard limit. While the highest noise level recorded was up to 94.3 dB, which exceeded 29.3 dB as compared to the standard. The area of Faizabad Rawalpindi is located in front of heavy traffic flow. The permissible noise level according to NEQS was 70 dB, the actual noise level at this location was found to

Table 2. Noise level data collected during December 2018-February 2019.

Sr. No	Noise levels and Noise Intensity values									
	Locations	Noise level S1 7:00 to 8:00am dB	Noise level S2 1:00 to 2:00pm dB	Noise level S3 5:00 to 6:00pm dB	Noise level S4 9:00 to 10:00pm dB	Noise level Mean dB	Noise level Max dB	Noise level Min dB	Noise intensity I W/m^2	Std. Dev.
1	Faizabad Rawalpindi	78.7	77.6	83.8	75.7	78.9	91.3	68.6	7.8 x10^{-5}	4.7
2	Pirwadahi Rawalpindi	85.4	88.8	87.9	78.2	85.1	95.6	70.0	3.2 x10^{-4}	6.2
3	6th Road Rawalpindi	68.4	67.8	79.3	67.2	70.7	89.6	62.0	1.2 x10^{-5}	6.5
4	I-9/3 Islamabad	71.5	75.8	79.2	75.0	75.4	85.0	64.2	3.4 x10^{-5}	4.6
5	Karachi Company Islamabad	69.2	69.3	68.7	67.4	68.7	75.3	61.3	7.3 x10^{-6}	3.5
6	Raja Bazar Rawalpindi	80.8	82.3	86.2	81.2	82.6	94.3	70.0	1.8 x10^{-4}	5.2

be 79.9 dB with the calculated intensity level of 9.9 x 10^{-5} w/m^2, which prominently exceeds about 10 dB from its standard value. At the same time, the highest noise level recorded up to 92 dB, which exceeded 22 dB from the specified limit. Location I-9/3 is an industrial zone in Islamabad. The allowable limit of noise level assigned by NEQS was 75 dB. The highest noise level at this location was 85.0 dB, exceeding 10 dB from the standard limit. Location of 6th road, Rawalpindi, is densely populated with a number of educational institutes and traffic load. According to NEQS, the allowable limit assigned to this location is 50 dB. The average noise level recorded was 71.0 dB, which exceeded about 21 dB from the standard limit with corresponding sound intensity levels were calculated as 1.26 X10^{-5} watt/m^2. The maximum level recorded of concern location was 89.6 dB, which exceeded the allowable standard of prominently 39.6 dB. The location of Karachi Company, Islamabad, was not found that noisy, but still, the recorded values exceeded NEQS. This location is also a commercial zone of Islamabad, and the allowable limit of noise level was 65dB. The highest noise level recorded at this location was up to 76.1 dB. The variation between the average values of recorded noise levels of first and second phases is shown in Fig. 2. It has been observed that with an increase in temperature, the humidity increased, resulting in an increased noise level. Corresponding intensity levels also increased as the noise level increased (Figs 2, 3). A similar interdependence of temperature, humidity, and noise level is reported in a recent study in which the effects of temperature and pressure on sound speed in sediments and their trends were analyzed [42]. Noise level comparison during winter (1st phase) and summer months (2nd phase) in the present study and the statistical analysis of data recorded during winter and summer months showed a significant variation in noise levels $p<0.001$ at all locations. Another study evaluated the interdependence of air temperature, radiant heat, wind velocity and noise intensity; it was revealed that less noise in forests positively affects other factors‘ intensity. Consequently, a forest setting is more comfortable for people than in an urban setting during the summers [43]. The psychological responses to physical environments are also significantly related to air temperature, relative humidity, radiant heat, and wind velocity. The temperature effect is highest in low and high-frequency ranges of noise. It has been found that the sound frequencies have a strong correlation with temperature and humidity [44]. Our results show a significant variation of noise levels data with temperature and humidity variation during winter and summer phases of data collection.

According to the study [45], it was reported that noise levels recorded at some of the critical locations in Rawalpindi exceed the limit of given standards. The study recorded a few Rawalpindi areas, indicating maximum noise levels of 90,77.8 and 101 dB, at Gordon College, Women college, and

Chandni Chowk, Rawalpindi, respectively. A study conducted in Faisalabad city aimed at measuring noise levels at two industries and other busy locations. The measured sound pressure levels were higher than the permissible limits at all the sampling locations during the morning, afternoon, and evening hours [46]. The reasons for the high levels of noise in the selected areas, including traffic areas, educational, commercial, and medical facilities, is their locations near busy roads and exposure to the high-intensity noise levels as previously described [47, 48]. Our study focused on more diverse areas of twin cities, including temporal and seasonal variations with noise data. There is a lack of awareness regarding noise pollution among ordinary people, especially the physical and social harms of noise. There are not many complaints regarding noise from any part of the community. That might be why no steps were ever taken by the authorities to reduce the noise pollution in selected areas. There is a disproportionate use of loudspeakers in Pirwadahi and Faizabad bus stops to attract the passengers, which is the reason for an increased level of noise. There are several car repairs and denting painting workshops at bus/HiAce stops, which prominently contributed to rising levels of noise at Pirwadahi, Rawalpindi location. It has been reported that noise related disorders are leading to infuriation and annoyance in people, hearing loss [49] and sleeping disorders [50-51].

The abundance of unapproved and unplanned stalls and shops in Raja Bazar, and the Pirwadahi location is responsible for the massive overcrowding and increased noise level. There are no proper and enough parking areas for the local vehicles in raja Bazar and 6th road Rawalpindi due to which massive congestion is observed for most of the time. There are many educational institutions located on 6th road Rawalpindi,

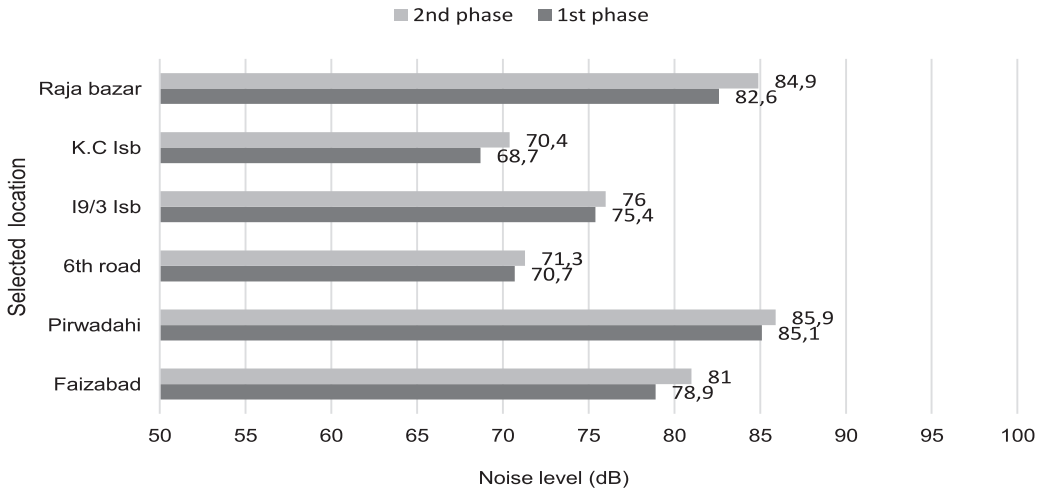

Fig. 2. Noise levels comparison during winter 1st phase and summer months 2nd phase

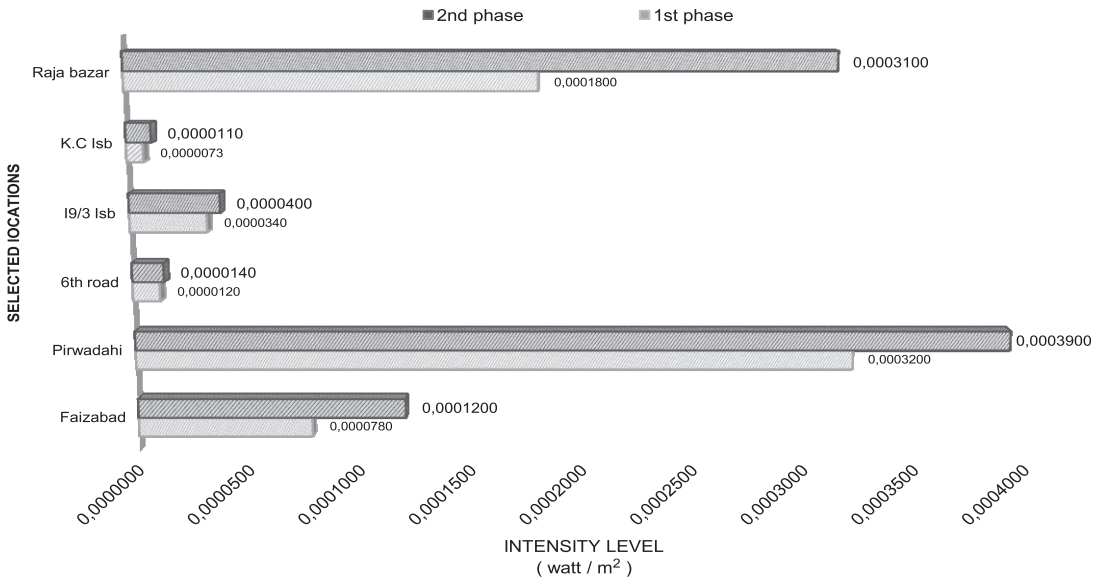

Fig. 3. Noise intensity comparison during winter 1st phase and summer months 2nd phase

Table 3. Noise level data collected during March-June 2019.

Noise levels and Noise Intensity values [2]										
S. No	Locations	Noise level S1 7:00 to 8:00am dB	Noise level S2 1:00 to 2:00pm dB	Noise level S3 5:00 to 6:00pm dB	Noise level S4 9:00 to 10:00pm dB	Noise level Mean dB	Noise level Max dB	Noise level Min dB	Noise intensity I W/m^2	Std. Dev.
1	Faizabad Rawalpindi	81.4	79.6	84.9	77.9	81.0	94.3	74.0	$1.2\ x10^{-4}$	4.6
2	Pirwadahi Rawalpindi	86.4	89.8	88.9	78.5	85.9	97.6	74.0	$3.9\ x10^{-4}$	6.3
3	6th Road Rawalpindi	68.5	68.6	81.5	66.7	71.3	89.6	64.0	$1.4\ x10^{-5}$	7.1
4	I-9/3 Islamabad	72.9	76.0	79.7	75.4	76.0	86.0	65.9	$4.0\ x10^{-5}$	4.7
5	Karachi Company Islamabad	69.7	71.9	71.9	68.2	70.4	77.0	63.2	$1.1\ x10^{-5}$	3.3
6	Raja Bazar Rawalpindi	81.1	83.5	89.1	85.8	84.9	95.3	74.6	$3.1\ x10^{s}$	5.0

Table 4. Average values of noise levels during December 2018-June 2019.

Noise levels and Noise intensity values					
Locations	Mean Noise level dB	Noise level Max. dB	Noise level Min. dB	Standard Deviation	Noise Intensity W/m^2
Faizabad Rawalpindi	79.9	92.0	72.2	4.4	$9.9x10^{-5}$
Pirwadahi Rawalpindi	85.5	96.4	72.0	6.0	$3.5x10^{-4}$
6th Road Rawalpindi	71.0	89.6	64.0	6.6	$1.3x10^{-5}$
I-9/3 Islamabad	75.7	85.0	65.1	4.5	$3.7x10^{-5}$
Karachi Company Islamabad	69.5	76.1	63.2	3.0	$8.9x10^{-6}$
Raja Bazar Rawalpindi	83.7	94.3	74.6	4.6	$2.3x10^{-4}$

and the observation of such a high noise level at this location is surprising as it can affect the educational activities at these institutes. Noise pollution in and outside the schools can disturb children's memory [52], learning ability [53], and hearing ability [54]. At afternoon times, high noise levels were found at the busy roads due to the pick and drop activity at off timings of the schools [55]. Overcrowding has become a foundation to increase the level of noise to a prominent range. Unplanned urbanization has severely damaged the natural green areas of Rawalpindi and is strongly contributing to noise pollution.

Based on noise pollution in the study area, various mitigation measures can be adopted as the recorded noise levels of all the selected locations exceeded NEQS and WHO standards. The use of loudspeakers should be minimized, and proper board systems should be implemented for public addressing purposes. Green patching walls should be used abundantly, which would reduce the noise levels significantly. Auto repairs workshops that produce prominent sound should be removed from the bus/HiAce stops and should only be in designated areas. Unapproved and unplanned stalls should be removed from the locations to clear the parking areas traffic and maximum utilization. The traffic management system should be improved and strict actions should be taken against overcrowding and violation of motor vehicle rules. Social and electronic media should be used to spread awareness regarding the harms of increased noise pollution. Moreover, specific and detailed legislation is needed to control noise pollution.

Conclusions

The results show that recorded noise levels at all locations exceeded NEQS. Noise levels and intensity levels were found higher during the summer months as compared to winter and affected by metrological conditions. Significant variation in noise levels was observed with seasonal and diurnal variations. However, more investigations are required to establish the effect of metrological parameters on noise levels. A national-level survey must be conducted to assess the noise level for major cities of Pakistan. The study will help provide a guideline and symmetric path to follow for Pakistan's concerned authorities to understand the severity of deadly pollution and take proper counter measures to protect public health.

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Conflict of Interest

The authors declare no conflicts of interest.

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