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GIS-Based Mapping and Assessment of Road Traffic Noise in and Around of Schools Situated Near Busy Roadside

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Abstract

This study was conducted of traffic noise which affected on urban traffic noise of selected roadside school as acoustic comfort for selected locations (near school buildings) of Burdwan town and the ambient noise was recorded during four different time periods (early morning, late morning, afternoon and evening). Geographical Information System (GIS) based Inverse distance weighting (IDW) interpolating technique was used to identify the vulnerability of noise pollution in mixed areas of schools. The different acoustic descriptor such as Leq, L90, L50, L10, noise climate (NC), traffic noise index (TNI) and noise pollution level (NPL) were evaluated, while a community study was also simultaneously conducted. The results revealed that the average Leq, L90, L50, L10 varied from 76.5 dB (A) to 78.6 dB (A), 58.2 dB (A) to 60 dB (A), 65.6 (A) to 67.3 dB (A) and 86.6 (A) to 94.5 dB (A), respectively. It was observed that the noise climate reached its peak in the afternoon (35.7 ± dB (A)) and was the lowest in the evening (27.8 ± dB (A)). The health data indicated that about 71% and 8% of the inhabitants near the schools were suffering from irritation and sleeping problems respectively. The similar correlation study revealed that Leq ($r = 0.484$, $p < 0.679$), L90 ($r = 0.871$, $p < 0.327$), and L50 ($r = 0.507$, $p < 0.662$) were strongly correlated with sleep disturbance. It may therefore be safely concluded that school children in the subject schools being exposed to the same levels of hazard as the residents in the immediate vicinity were probably suffering from similar problems.

Keywords GIS-IDW; Noise parameter; Roadside school; School children; Traffic noise

Research Article

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1. Introduction

Noise is defined as unwanted noise that interferes with normal activities such as sleep, thinking, concentration, studies and recreation besides being the root cause of disturbance and annoyance [1-2]. Nowadays, due to the rapid growth of urbanization and subsequent environmental understanding, public health is under a huge threat and this leads to environmental control measures that are supposes to minimize the pollution load. Among the various pollutants, noise is consider under the air (prevention and control of pollution) Act, 1981 [3]. In recent times, the environmental noise become steadily increased both in intensity and spread, which has emerged as a matter of grave concern for society [4-5]. According to studies conducted by the European Environmental Agency, the main source of environmental noise generated by vehicular transport [6]. Noise level greater than 75 dB (A) is enough to cause annoyance, aggressive behaviour and sleep disorder [7-8]. Moreover, continuous exposure to noise level of 65 dB (A) leads to hypertension, and when the exposure level increases to 75 dB (A), it may additionally raise stress level, cause abnormal heart rates and even result in loss of hearing [9]. However, environmental regulating authority, WHO, clearly recommended that 30 dB (A) in resting room during night time for good quality of sleep and less than 35 dB (A) in classroom is the appropriate level of noise for proper teaching-learning process. World Health Organization also recommended that less than 40 dB (A) should be the average noise level at the outside of bedroom in order to avoid the adverse health effect during night time [10].

According to Mondal [11], huge increase of vehicle population in Indian cities and towns are due to rapid urbanisation and industrialisation. Various types of environmental noise from sources such as railways, road traffic, construction activities and aircraft etc., have been found to directly affect reading [12]. It has also been reported that noise level of around 70 dB (A) outside schools leads to a drastic fall in children's attention [13-14]. Previous studies [15-16] also pointed out that high frequency noise was found to adversely affect cognitive ability and academic performance of school children, in addition to reducing their level of motivation.

According to Babisch [17], associated with traffic noise is cardiovascular disease along with some non-chemical outcomes such as anxiety, stress, annoyance, sleep disturbance etc. [18-19]. Very recently, it has also been reported that noise is also related to undesirable metabolic outcomes [20]. Similarly, Sorensen et al. [21] established a positive relationship between road traffic noise and a higher risk of diabetes as well as higher BMI and waist circumference [22-23]. Previously Eriksson et al. [24] reported that aircraft noise was closely related to waist circumference. Apart from these, road traffic noise exerted a strong influence on the physiological processes of human beings. In other words, this means that noise has a direct relationship with the secretion and proper functioning of hormones. Vehicular noise is closely linked with sleep disturbance [19]. Improper or irregular sleep pattern is due to dysfunctioning of various hormones such as leptin and ghrelin, which are directly associated with human metabolism [25-26]. Sleep refreshes and energises the body and mind and inadequate and improper sleep leads to reduced energy expenditure, altered thermoregulation and increased fatigue [27].

Many sectors of our society are severely affected by intense noise. However, this noise also impacted on cognitive and intellectual activity of students also [28]. Therefore, a comprehensive assessment of noise is the highest priority among the researchers. Noise can be precisely recorded through a geographical form which is coloured according to the noise level in the targeted area. However, this graphical form may be represented by contour lines, which may be used to make a boundary between different noise levels in an area. Very recently, noise and urban planning have extensively studied based on noise mapping [29-30]. Various noise parameters such as Leq, L90, L50, L10, NC, TNI, NPL etc., were extensively used for better assessment of road traffic noise and their impact on society.

Burdwan city (23º14’N, 87º52’ E) is the district headquarters of Purba Bardhaman district and a municipality in the state of West Bengal. This city is situated 100 km away from the state capital, Kolkata. According to the census report [31], the population of the city is 347016 and the total area is 26.30 km2. The mean elevation is 30 m above mean sea level. A sharp growth of vehicular transport in the last decade results in a significant increase of traffic noise in the city. The adverse impact of increased noise levels due to exponential growth of vehicular population was highlighted in previous works [32-34], which also clearly demonstrated, the resultant noise levels were much higher than the threshold noise level. Doygun and kusat [8] highlighted that traffic noise was mainly to blame for the detrimental effects on heart rates and for causing hearing loss, among others. According to the World Health Organization guidelines [35] noise intensity in the environment in the vicinity of schools should not exceed 35 dB (A).

Noise mapping is very important to urban plan. In particular, structural and areas such as schools, hospitals and parks away from noise pollution are of primary concern. Generally GIS-based commercial software was used to create noise maps, which consists of initially the production of grid points. These points are taken for bifurcation, it helps to explain a large area where the possibility of noise is risky and to determine the measurement points of noise disturbance [36]. Therefore, a comprehensive evaluation of the impact of the noise generated by the road traffic on school children and on residents of the locality is absolutely necessary. Keeping this in mind, a study was conducted to evaluate the noise level, community health and noise mapping around ten selected schools located on busy roads in the city of Burdwan, West Bengal, India.

2. Materials and Methods

2.1. Overview and site selection

Ten schools were selected near the urban roads in Burdwan town (location Fig. 1) were chosen for the field examination. The field position based on geographic location by GPS and road side congested area, where major road traffic noise produces around significant acoustic environments. This located area are mapped through Google Earth position based by QGIS software, which was shown in Fig. 2. All schools are near adjacent in sub-arterial roads, here dominating mainly road traffic noise and open area local activity of noises that combined effect on a significant terms of annoyance. The weather parameters are measured during sampling time from the sample sights (Table S1).

At the initial stage, the baseline data were collected from ten different places of Burdwan city. All the ten locations were selected as per the requirement of the present research and for the fulfillment of the current objectives. All the locations were near school buildings, namely 1) School H (23.26181°N, 87.83913°E), 2) School B (23.23895°N, 87.86709°E), 3) School G (23.24281°N, 87.85839°E), 4) School J (23.23734°N, 87.84987°E), 5) School E (23.24051°N, 87.85913°E), 6) School F(23.2427°N, 87.84376°E), 7) School I (23.23527°N, 87.8612°E), 8) School C (23.24007°N, 87.83354°E), 9) School A (23.23859°N, 87.87158°E) and 10) School D (23.2403°N, 87.86575°E). In the study area summary table (Table 1), it was noted that the road width varied from 3 m to 24 m at the different study area locations. The narrowest road width was recorded at School D (3 m) and total vehicle density there was also low, 308 during the early morning time (8-9 a.m.). It was also interesting to note that only light vehicles were allowed to ply on that particular road, not heavy or medium vehicles.

2.2. Noise Measurement

Noise was recorded by a digital noise meter (Lutron SL-4030) and geographical location was recorded by GPS (GPS-12, Garmin). Mainly four time slots were considered (early morning: 8-9 am; late morning: 11am-12 noon; afternoon: 2-3 pm; and evening time: 6-7 pm). Vehicle density was counted and recorded under three distinct categories as heavy, medium and light vehicles.

2.3. Acoustic descriptors

Different Acoustic descriptor such as Leq, L10, L50, L90, and Noise Climate (NC), Noise Pollution Level (NPL), and Traffic Noise Index (TNI) were calculated [37] by following standard formula (Eq. 1-4):

Table 1 Description of study site

Sl. No.	Name of the School	Lattitude	Longitude	Site description				Vechile Type	Building Patterns				Mean Vehicle Density
				Road Width(m)	Road Morphology	Road Materials	Width of Footpath(m)		No. of windows towards road	Distance from school gate(m)	Window material	Storey	
1	Burdwan High Madrasha (H)	23.26181	87.83913	24	Smooth	Pitch	3	H M L	32	4	W, G	2	160 340 2257
2	Burdwan municipal Boys high school (B)	23.23895	87.86709	12	Smooth, conjusted	Pitch	3	H M L	18	5	W	2	92 448 3400
3	Harisava Hindu Girls High School(G)	23.24281	87.85839	4.5	rough, conjusted	Pitch	1	M L	21	2	W	3	30 1775
4	Burdwan Raj Collegiate School(I)	23.23734	87.84987	6	Smooth	Pitch	1	H M L	16	2	W	1	10 75 1246
5	Burdwan CMS High School(E)	23.24051	87.85913	8	Smooth, conjusted	Pitch	2	M L	24	3	W	2	22 2411
6	Burdwan Sriramkrishna Sarada Pith School(F)	23.2427	87.84376	3.5	Smooth	Pitch	2	M L	16	20	W, G	2	20 1210
7	Burdwan Bidhyarthi vaban Girls high School(J)	23.23527	87.8612	4.5	rough, conjusted	Pitch	2	M L	30	4	W	2	20 1933
8	Rathtala Monohardas Balika Bidhyalaya(C)	23.24007	87.83354	3.5	Smooth	Pitch	2	H M L	36	3	W	2	9 25 1290
9	Shiba Kumar Harijon Vidhyalaya(A)	23.23859	87.87158	3.5	Smooth	Pitch	1	M L	24	2	W	3	27 940
10	Burdwan Banipith high School(D)	23.2403	87.86575	3	rough, conjusted	Pitch	0	L	20	5	W, G	3	351

Note: H: Heavy, M: Medium, L: Light; TR: towards road; W: wooden, G: glass

$$L_{eq} = 10log\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2}\frac{p_A^2(t)}{p_0^2}dt \quad (1)$$

$$TNI = 4 * (L_{90} - L_{10}) + (L_{90} - 30) \quad (2)$$

$$NPL = L_{eq} + (L_{10} - L_{90}) \quad (3)$$

$$NC = (L_{10} - L_{90}) \quad (4)$$

Various noise descriptors [38] (Cohn and McVoy, 1982) are as follows:

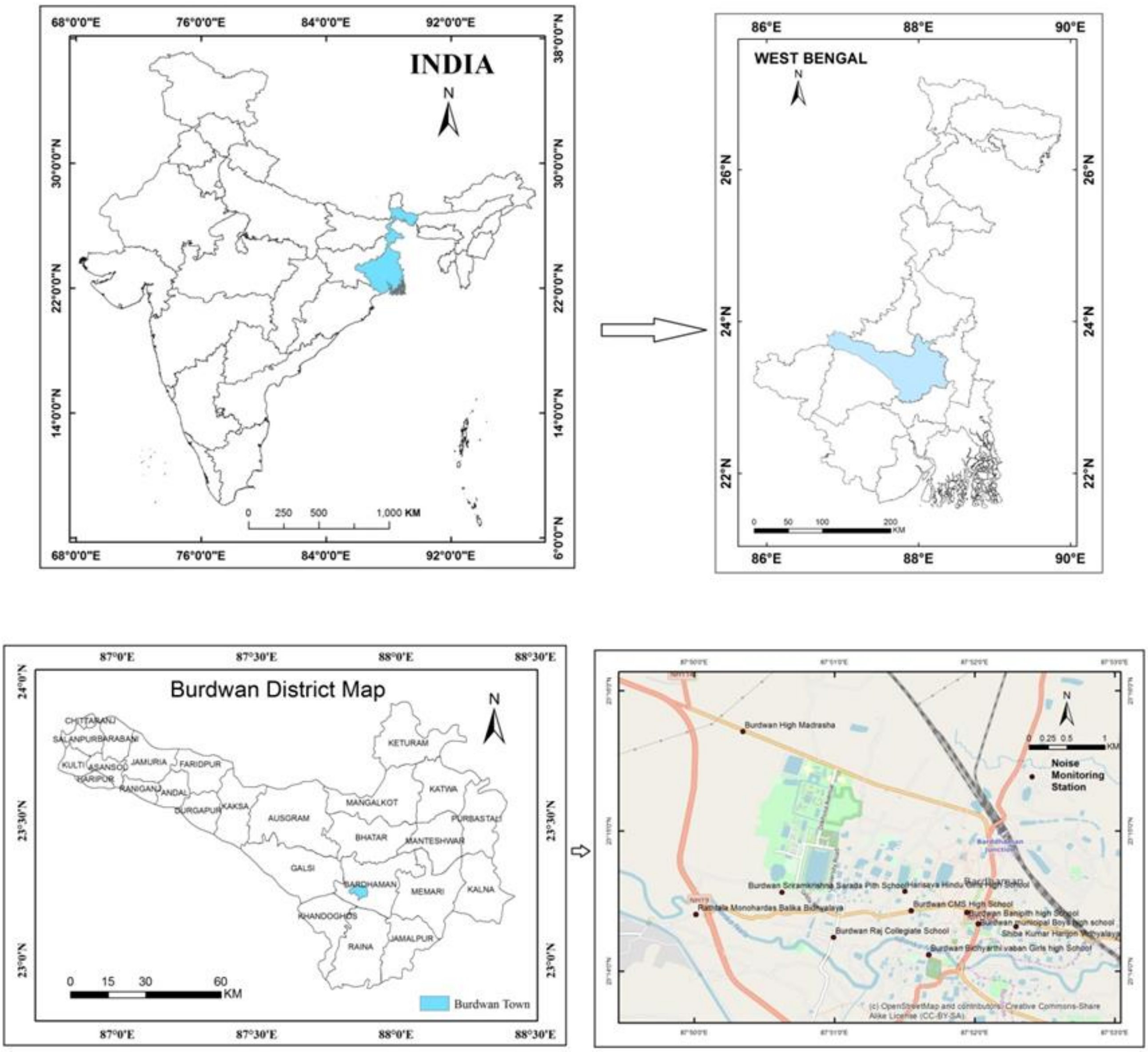

Fig. 1. Study area location map

L10: A specified dB (A) level which is exceeded ten percent of the time during the whole period of measurement.

L50: A specified dB (A) level which is exceeded fifty percent of the time. It is statistically the midpoint of the noise readings.

L90: A specified dB (A) level which is exceeded ninety percent of the time during the whole period of measurement.

Leq: The equivalent continuous dB (A) level which has the source energy as the original fluctuating noise for the same period of time.

2.4. Community study

Community study was conducted by following the standard procedure [39]. A questionnaire was constructed in English and then translated into Bengali. The questionnaire consists both open-ended and structured questions covering the areas like demographic characteristics, economical status, type of house including total windows and doors number and direction of windows, distance from road, health status, comfort of the working environment, sound sources as well as noise related problems. The entire interaction with the roadside inhabitants were random. Every question had three options (yes/ no/ never) following the three point Likert scale.

2.5. Assessment of acoustic comfort

From the previous literature, the questionnaires were perfectly designed for different schools from urban area, sampling points, size of campus, number of students, and adjacent road noise levels. All sights were selected by the survey contents and collected basis of information according to age, gender, weight, and academic achievements in class, which including the question, (i) is class room either noisy or quiet? (ii) Is class most annoyed during study/examination/ lessening? (iii) Which vehicles noise more effectiveness to annoyance? (iv) Vehicle abundance and open noise availability, (v) classroom size and student availability? (vi) Lesson time and disturbance? etc. Total 100 questionnaires were issued and 50 students were selected randomly each classes. The selected class not be measured on ages, but classes were chosen from based V to class VII. From 500 number of students are evaluated, whereas 53.33% of male and 46.77% of female. The questions were consisted of simple question answers pattern with single choice answer pattern. For acoustic comforts to different noise sources, such as highly annoyed, rather annoyed, moderate, and comfortable. Finally, the mean value were collected to evaluate the comfort score of all school.

2.6. Interpolation methods onto noise mapping

Noise mapping was done with the help of ArcGIS 10.3 software using IDW interpolation method. This study was compared with noise mapping in the time variances, whereas early morning, late morning, afternoon time, and evening time. The noise values were computed using as Lmin, Lmax and Leq. This method was produced for optimum results, which comparison between 10 different schools according to noise level. Inverse distance weighted (IDW) as interpolation method using points, the noise value was carried out at point i (N0), which are calculated from following equation

(5)

Where, expression as n, Ni, Pi were represented according to the number of measurement points, positions of the noise value in number i, and the weight of the noise at i position, respectively. The weight Pi was calculated from Eq. (6), which is based on distance function into reference point and the interpolation point, distance between closer points to higher point.

(i=1, 2, 3, 4, 5…..n) (6)

Where, di is distance into horizontal and interpolation point regarding (x0, y0) and corresponding reference points at (xi, yi), k namely the power of the distance and expressed as . Pi was calculated using the Gaussian function expressed as:

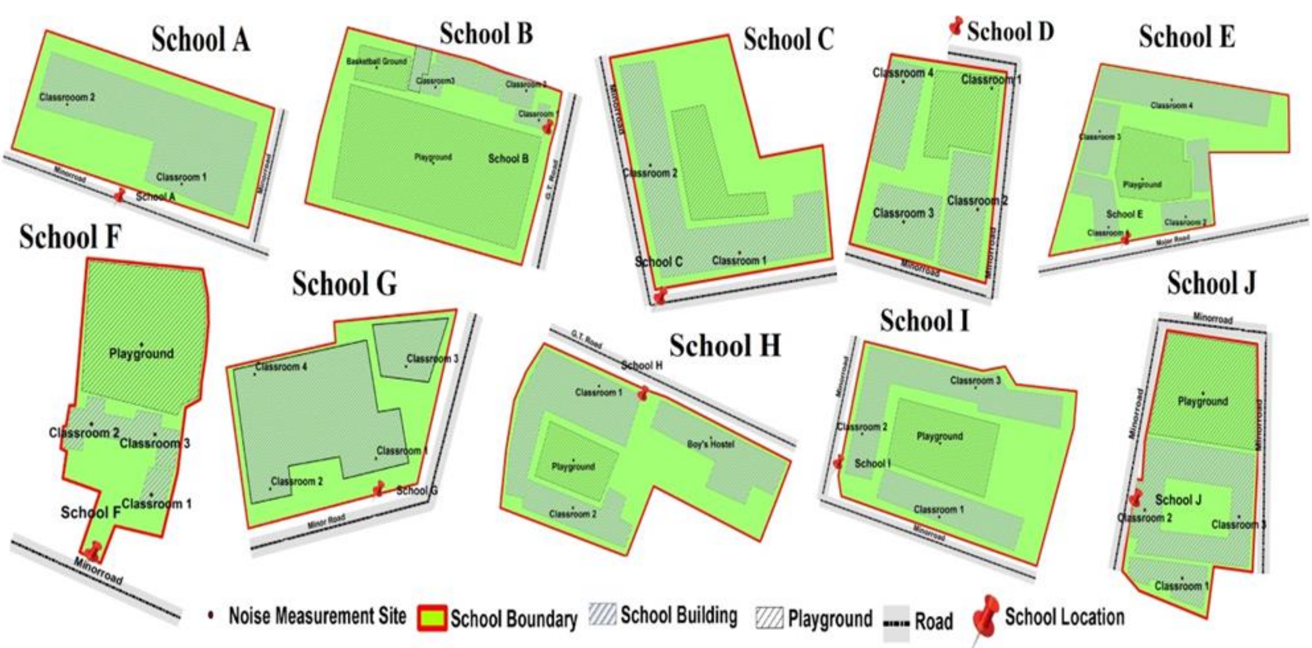

Fig. 2. Study of noise located sights and 2D overview maps of the ten roadside schools

(i=1, 2, 3, 4, 5…..n) (7)

This IDW method, the reference points around the interpolation point was used to estimate noise value. The reference point was conducted from study area (schools), and interpolation was collected and mapped into contour plot for area pointing.

2.7. Statistical analysis

The collected data were analyzed by applying basic statistics with the help of SPSS software (SPSS 2.0). Pearson correlation and one-way ANOVA with significant level $p < 0.005$ was considered. Origin 8.5 software was used for construction of all figures and for formula writing, MATLAB software was used.

3. Results and discussion

3.1. Field measurement acoustic results

From field acoustic results, the maximum vehicle density in the early morning (8-9 a.m.) slots were recorded at School B and out of a total of 3294, the category wise composition of vehicles was

2% heavy, 12.2% medium and 85.8% light vehicles per hour (Table 1). Similarly, other high vehicle density zones were at School H (5.4% heavy, 11.3% medium and 83.3% light vehicles per hour), School G (0.1% heavy, 1.5% medium and 98.4% light vehicles per hour), School J (1.2% heavy, 6% medium and 92.8% light vehicle per hour), School E (0.8% medium and 99.2% light vehicle per hour), School F(0.2% heavy, 1.4% medium and 98.4% light vehicle per hour), School I (0.1% heavy, 0.7% medium and 99.2% light vehicle per hour), School C (0.5% heavy, 1.4% medium and 98.1% light vehicle per hour), School A (0.1% heavy, 2.5% medium and 97.4% light vehicle per hour) and School D (100% light vehicle per hour). This was followed by recording late morning data in all the studied locations. It was amply clear from road surface characteristics data that in all the study areas, the road surfaces were reasonably smooth except near School G, School I and School D. Around 75% of the roadside buildings at the different locations were found to be two-storeyed brick and mortar houses and were situated on an average 1.5m away from the road. Most of the buildings (around 85%) had roadside windows and only around 15% of the buildings had road facing glass windows. It is apparent from Fig. S1, the traffic noise index was high in the afternoon at all the studied locations. In order to assess the overall impact of noise on the academic atmosphere, several Acoustic descriptors such as Leq, L10, L50, and L90 were calculated and the results have been presented in Table 2. It may be noted that Leq values varied from 69.7 dB (A) to 86.9 dB (A), L10 values varied from 83.5 dB (A) to 96.2 dB (A), L50 values varied from 58.9 dB (A) to 75.5 dB (A) and L90 values varied from 52.6 dB (A) to 63 dB (A) respectively. Similarly, Noise Pollution Level (NPL), Traffic Noise Index (TNI) and Noise Climate (NC) were also analyzed and the results are as depicted in Fig. S2-S4. The results clearly indicate that out of the ten locations, Noise Pollution Level was the highest at School B (NPL 115.7 dB (A)). This can perhaps be attributed to heavy vehicle density and motor bike horn (Heavy vehicle 2%, Medium vehicle 12.2% and light vehicle 85.8% per hour) owing to its location near G. T. Road, an arterial road in the city (Fig.S4). Traffic noise is a problem common to all developed and developing nations [12, 40]. The graphical presentation of Noise Pollution level (NPL) and Traffic Noise Index (TNI) are as depicted and it is clear that noise pollution is the highest in the afternoon.

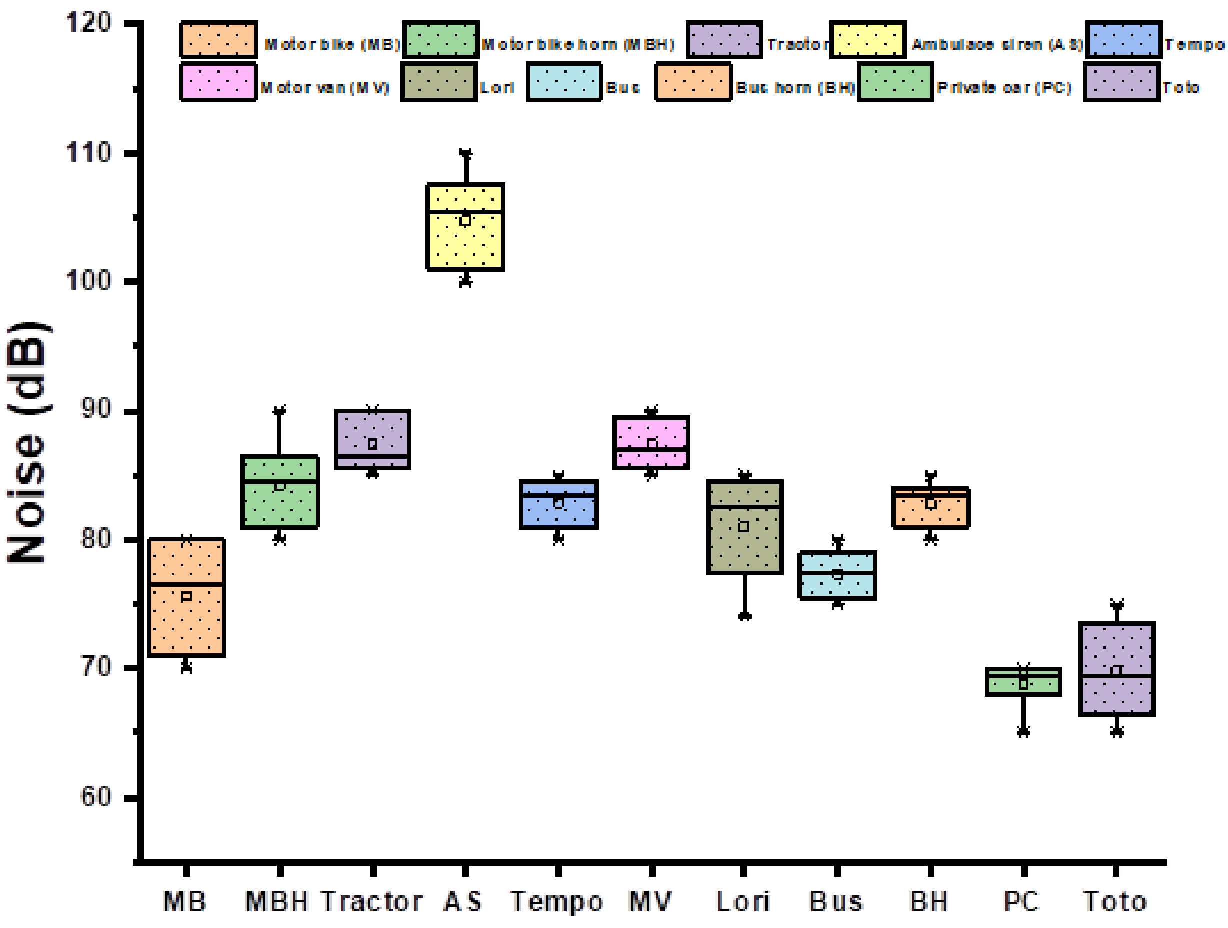

Fig. 3 Noise discharges by different types of vehicles in studied locations

Similarly, during the late morning hour (11 a.m.-12 p.m.), the maximum vehicular density of 4736 per hour was also recorded at School B and the composition of vehicles was 2.1% heavy, 11% medium and 86.9% light vehicles per hour (Table 1). Vehicular density in the said time slot at other locations were as follows; At School H (4.8% heavy, 10.4% medium and 84.8% light vehicles per hour), School G (1.7% medium, 98.3% light vehicles per hour), School J (1% heavy, 6% medium and 93% light vehicles per hour), School E (1.2% medium and 98.8% light vehicles per hour), School F(0.1% heavy, 1.4% medium and 98.5% light vehicles per hour), School I (0.2% heavy, 1.2% medium and 98.6% light vehicles per hour), School C (0.7% heavy, 2.9% medium and 96.4% light vehicles per hour), School A (0.2% heavy, 3.4% medium and 96.5% light vehicles per hour) and at School D (100% light vehicles per hour). It was been found that Leq value varied from 68 dB (A) to 84.9 dB (A), L10 varied 83.2 dB (A) to 95.9 dB (A), L50 varied from 57.4 dB (A) to 73.7 dB (A) and L90 varied 55.4 dB (A) to 66.6 dB (A). The highest Noise Pollution Level (NPL) found at School G [NPL 115.8 dB (A)], because of that the particular school was situated in a very congested area (Road width-4.5m) with the concentration of a very large number of health institutions. Main noise pollution sources of this area are ambulance and motor bike horn (Medium vehicle 32 and light vehicles 1906 per hour). TNI and NC were also found to be high at School G (TNI 158.8 dB (A) and NC 31.5 dB (A)) (Fig. S1 & S3).

Table 2 Measured noise level in various time for selected sites throughout Burdwan town, West Bengal

School	Noise monitoring time															
	Early Morning (8-9 am)				Late Morning (11-12 pm)				Afternoon (2-3 pm)				Evening (6-7 pm)			
	L_{eq}	L_{10}	L_{50}	L_{90}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{eq}	L_{10}	L_{50}	L_{90}
A	73.6± 6.5	87.5± 6.25	63.2± 5.87	57.3± 5.39	73.1± 5.33	86.6± 4.31	62.2± 3.47	55.5± 3.66	69.7± 3.45	87.5± 3.22	60.8± 6.22	53.0± 3.77	72.0± 3.24	86.4± 2.45	61.2± 3.44	55.4± 3.23
B	86.9± 5.78	93.5± 6.5	75.5± 6.11	63.0± 5.39	82.6± 5.35	91.3± 4.31	71.8± 4.35	61.7± 3.71	79.0± 3.26	92.0± 3.66	71.3± 6.19	63.1± 3.25	81.0± 3.26	94.2± 5.43	70.2± 3.56	61.5± 3.45
C	70.9± 5.89	83.5± 6.5	60.3± 6.43	54.7± 5.39	76.8± 5.39	85.7± 4.31	66.1± 3.72	63.3± 3.67	73.6± 3.65	84.3± 3.22	62.7± 6.23	56.6± 3.56	75.2± 3.68	78.5± 5.72	64.7± 3.56	58.8± 2.34
D	70.6± 5.77	83.6± 6.5	59.8± 6.15	52.6± 5.39	73.0± 5.37	83.2± 4.31	62.4± 3.88	55.4± 4.66	69.9± 3.55	78.1± 3.14	59.0± 3.24	54.3± 3.15	72.2± 4.11	80.2± 5.34	61.3± 2.45	56.8± 2.46
E	81.1± 5.66	94.1± 3.11	70.1± 6.44	62.3± 5.39	84.9± 5.36	90.2± 4.31	73.6± 3.67	66.6± 4.23	81.4± 3.65	99.2± 3.24	70.2± 3.27	60.4± 3.25	80.7± 4.23	91.0± 3.22	69.7± 2.44	62.9± 3.11
F	69.7± 6.01	89.4± 4.24	58.9± 6.35	54.9± 5.39	68.0± 5.39	85.2± 4.31	57.4± 3.55	55.7± 5.27	67.1± 3.67	86.4± 3.55	56.6± 3.46	48.1± 2.91	73.6± 3.22	86.6± 4.65	62.7± 2.57	56.2± 2.33
G	81.1± 6.11	96.2± 4.25	70.4± 6.53	61.0± 5.39	84.4± 5.12	94.4± 4.31	73.8± 3.78	62.9± 3.56	107.4± 3.46	118.0± 3.41	86.3± 4.15	79.2± 3.11	80.9± 2.45	92.4± 4.24	69.8± 4.77	59.7± 2.56
H	86.4± 6.74	90.8± 4.96	75.2± 6.67	61.5± 5.39	83.6± 5.34	91.7± 4.31	72.7± 3.65	63.1± 3.67	85.4± 3.55	103.7± 3.67	78.3± 3.24	62.2± 3.02	77.8± 3.44	82.2± 5.44	66.6± 5.34	60.5± 2.33
I	72.4± 6.49	87.7± 5.08	61.8± 6.26	55.4± 5.39	73.8± 5.77	88.2± 4.31	63.2± 3.75	57.0± 3.44	76.7± 3.15	99.5± 5.43	65.9± 3.17	56.1± 3.55	76.5± 4.34	87.7± 3.24	65.9± 5.27	59.5± 2.37
J	76.4± 6.26	86.5± 5.07	65.6± 6.12	59.1± 5.39	78.3± 5.67	85.6± 4.31	67.7± 4.29	58.7± 3.41	75.8± 3.42	96.0± 6.12	62.0± 3.25	54.3± 2.67	75.4± 4.27	86.6± 2.46	64.3± 6.11	56.2± 1.37

In the afternoon period, the highest vehicle density of 4308 was recorded at School B and the composition of vehicles was 2.6% heavy, 9% medium and 88.4% light vehicles per hour (Table 1). Similarly, other locations were also found such as School H (7.6% heavy, 14.6% medium and 77.8% light vehicles per hour), School G (0.3% heavy, 2.2% medium, 97.5% light vehicles per hour), School J (0.5% heavy, 7.9% medium and 91.6% light vehicles per hour), School E (0.8% medium and 99.2% light vehicles per hour) (Fig. S4), School F(0.1% heavy, 1.8% medium and 98.1% light vehicles per hour), School I (0.1% heavy, 0.5% medium and 99.4% light vehicles per hour), School C (0.8% heavy, 1.6% medium and 97.6% light vehicles per hour), School A (0.4% heavy, 2.5% medium and 97.1% light vehicles per hour), School D (100% light vehicles per hour) (Fig. S4). During afternoon time, vehicle density was found to decrease more or less at all locations. It was recorded that Leq value varied from 67.1 dB (A) to 107.4 dB (A), L10 varied from 78.1 dB (A) to 117.9 dB (A), L50 varied from 56.6 dB (A) to 86.3 dB (A), L90 varied from 48.1 dB (A) to 79.2 dB (A), NPL varied from 146.1 dB (A) to 93.7 dB (A), TNI from 204.3 dB (A) to 119.4 dB (A) and NC varied from 43.4 dB (A) to 23.8 dB (A). NC was found to be the highest at School I. Banerjee et al. [32] mentioned that the TNI was lower level of in the industrial town of Asansol, India. Noise discharges by different types of vehicles were studied in locations wise and highest showed noise intensity from ambulance siren (100-110 dB) [41] (Fig. 3).

Table 3 Acoustic Descriptors of different time with one way ANOVA studies

Acoustic Descriptors	Early Morning	Late Morning	Afternoon	Evening	One Way ANOVA df=(3, 36)
L_{10}	89.3 (86.6, 92.0)	88.2 (86.0, 90.4)	94.5 (87.4,101.6)	86.6 (76.5, 96.6)	F=2.479, p < 0.077
L_{50}	66.1 (62.2, 70.0)	67.1 (63.5, 70.6)	67.3 (61.5, 73.1)	65.6 (58.9, 72.3)	F=0.148, p < 0.930
L_{90}	58.2 (55.9, 60.5)	60.0 (57.5, 62.5)	58.7 (53.5, 64.0)	58.8 (53.8, 63.7)	F=0.215, p < 0.885
L_{eq}	76.9 (72.9, 81.0)	77.9 (74.2, 81.5)	78.6 (71.4, 85.8)	76.5 (69.7, 83.3)	F=0.157, p < 0.924
NC	31.1^{ab} (29.6, 32.6)	28.2^{b} (26.3, 30.2)	35.7^{a} (31.6, 39.9)	27.8^{b} (18.8, 36.9)	F=6.448, p < 0.001
TNI	171.8^{ab} (167.6, 176.0)	142.8^{b} (136.1, 149.6)	171.7^{a} (153.6, 189.8)	140.1^{b} (103.7, 176.5)	F=5.767, p < 0.003
NPL	117.3 (110.9, 123.7)	106.1 (102.3, 109.8)	114.3 (104.9, 123.7)	104.4 (91.5, 117.2)	F=2.148, p < 0.111

During evening (6-7 p.m.), vehicle density was noticeably lower and noise pressure level also was markedly less. Vehicle density at those ten zones during the period were followed : School H (6.6% heavy, 15.4% medium and 78% light vehicles per hour), School B (2.6% heavy, 14% medium and 83.4% light vehicles per hour), School G (1% medium, 99% light vehicles per hour), School J (0.2% heavy, 3.2% medium and 96.6% light vehicles per hour), School E (0.8% medium and 99.2% light vehicles per hour), School F(1.1% medium and 98.9% light vehicles per hour), School I (1.2% medium and 98.8% light vehicles per hour), School C (5% heavy, 1.5% medium and 98% light vehicles per hour), School A (1.9% medium and 98.1% light vehicles per hour), School D (100% light vehicles per hour) (Fig.2). In the said time interval, Leq varied between 80.96 dB (A) to 72.02 dB (A), L10 varied between 78.5 dB (A) to 94.1 dB (A), L50 varied from 70.2 dB (A) to 61.3 dB (A), L90 varied from 61.5 dB (A) to 55.4 dB (A), NPL varied from 113.7 dB (A) to 94.9 dB (A), TNI varied from 162.2 dB (A) to 107.7 dB (A) and NC varies from 32.7 dB (A) to 19.7 dB (A). The leq value at all locations was found to exceed the permissible limit of ambient air quality standards as adopted by MoEF [3]. According to WHO [35], the noise pollution negatively impacted on urban environment and community health.

Statistical analysis of various noise parameters are presented in Table 3. It was clearly demonstrated that L50, L90, Leq and NPL are not statistically significant ($p < 0.007$, $p < 0.930$, $p < 0.885$. and $p < 0.111$) between different time periods of recording the noise in selected study points. However, NC and TNI showed statistically significant ($p < 0.001$, and $p < 0.003$) between different time period. A gain Post hoc test revealed that the NC at afternoon statistically ($p < 0.05$) different from late morning and evening time. Similarly, traffic noise index showed significantly different from late morning and evening time. Almost similar observation was reported by Esmeray et al. [12].

3.2. IDW interpolating for Noise mapping

For the purpose of acquiring comprehensive knowledge about the variations of vulnerable noise intensity at different locations of the study area, a contour map was drawn by the application of ArcGIS 10.3 software using IDW interpolation method. Four contour maps were drawn for different time periods as vulnerability of noise pollution (early morning, late morning, afternoon and evening) (Fig.4A). The results demonstrated for noise mapping in the early morning, it is clear that two locations namely, near School H, and School B were truly vulnerable. However, in the late morning, all the study areas showed high noise intensity except School F (Fig. 4B). In the afternoon session, only one area, the vicinity of School G showed highest noise intensity (Fig.4C). Whereas, the other study points showed moderate noise intensity. A similar situation was observed in all areas except near School J, School C and School A, where intensity was found to have been reduced drastically in the evening time (Fig.4D). It is however interesting to note that noise intensity near School I and School B increased appreciably in the evening. Similar noise monitoring through noise mapping was done by Paschalidou et al. [42] at Egnatia motorway, northern Greece.

3.3. Impact of noise on Community

A community study was initiated at different places of Burdwan town, where noise from motor vehicles was recorded by noise meters. Three distinct age groups were chosen for the community study and the age groups were 1) less than 30 years, 2) between 30 to 60 years and 3) more than 60 years. Various health parameters such as irritation sleep disturbance, etc. and noise related problems were the main problems faced by the studied cohort [47, 35]. Previous research also demonstrated that road traffic noise could cause higher health risks such as diabetes [21], abnormal BMI and higher waist circumference [23] as well as sleep disturbance [19], etc. According to Pirrera et al. [48] noise is directly related to early awakening and sleep state changes. Insufficient sleep leads to disruption of secretion of hormones such as leptin and ghrelin which

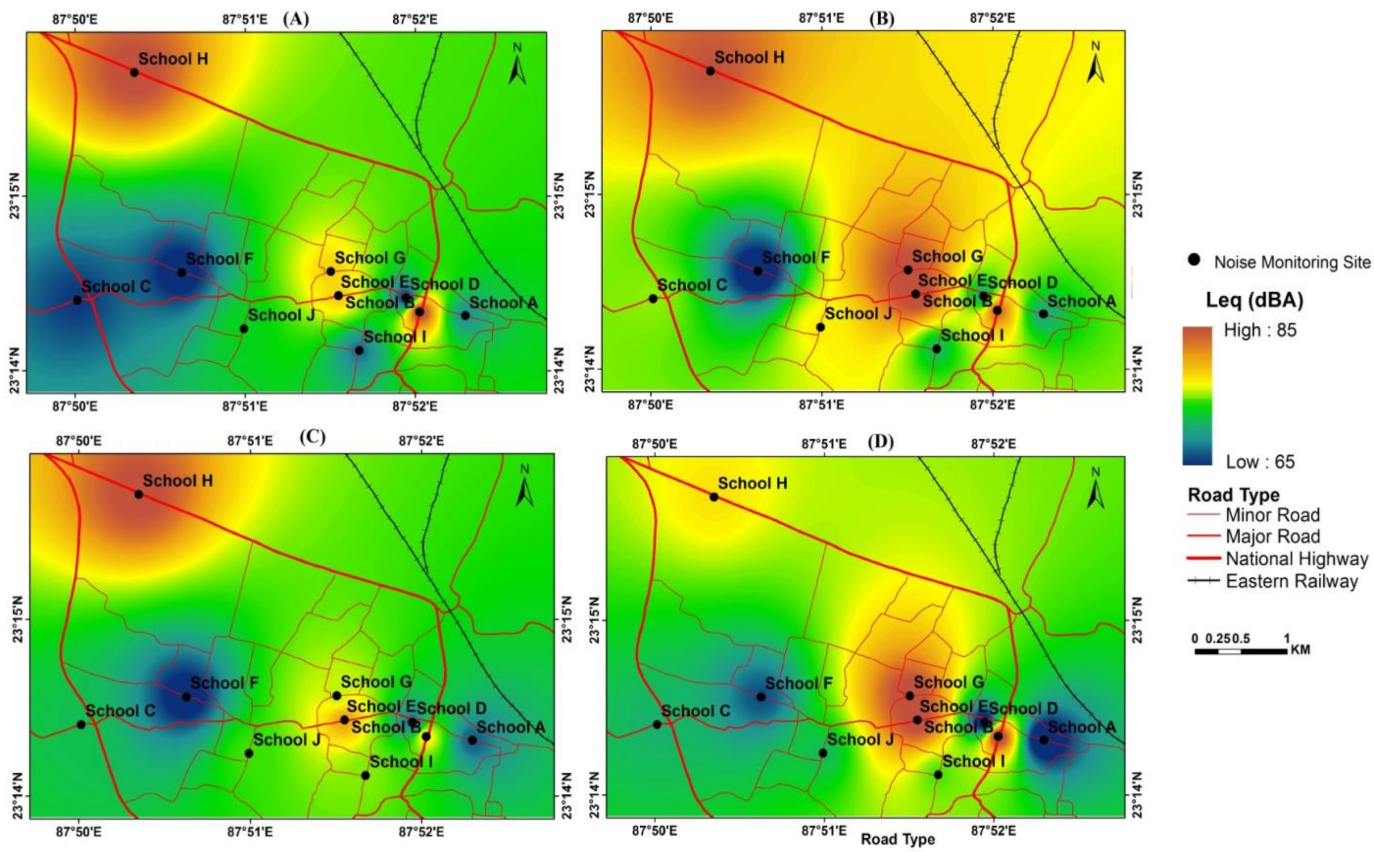

Fig. 4 Contour plot showing the noise mapping of ten selected schools (A) early morning time, (B) late morning, (C) afternoon time, and (D) evening time

were considered. A total of 236 people took part in the study. 52% of the respondents reported being extremely irritated by traffic noise and 8% of the respondents reported sleep disturbance due road traffic noise (Fig.S5). As we know that lack of sleep leads to many physiological problems like cardiovascular, endocrine, immune and even nervous system disturbance including hypertension and anxiety [43-44]. Therefore, the diversity of non-auditory effects are more than auditory effects induced by traffic noise [45]. Almost similar irritation status due under noise exposure was reported by earlier researchers [46]. The recorded results showed that irritation due to noise exposure varied from 4.35% to 14.28% in the age group less than 30 years and the values ranged from 12.90% to 60.71%. The age group more than 60 years reported less irritation from noise exposure. The levels of irritation recorded in the study areas near School I and School G were 71% and 66% respectively. The noise-induced sleep disorder, annoyance and stress are also associated with metabolism [25-25], reduction of energy expenditure and increased fatigue [27]. However, Babish [49] also suggested that hormonal disruption might activate the hypothalamus-pituitary-adrenal (HPA) system which in turn led to enhancement of such hormones as noradrenaline, adrenaline and corticosteroids.

3.4. Evaluation of acoustic comfort

Acoustic comfort of the study schools were evaluated by considering various input variables (sampling points, size of campus, number of students, and adjacent road levels etc.) and results were depicted in Fig.5a. The assessment each student through questionnaires, all students are taken unformed at class bases, n=100, and calculated student activity during acoustic time. The results showed on affecting in classroom attention or classroom activity, 10 schools were rectified the highest impact, when test or exercise time (45.55% ± 2.45) (Fig. 5b). Disturbances of student's responses to rather annoyed suffer maximum school students, among 51.33% regardless close to roadside noise. All zone of schools for aquatics comforts are interpreted using factor correlation, the highest comfort score showed corresponding as School G > School H > School B > School E > School J > School I > School C > School A > School D > School F, due to intensified gained of the noise level (LAeq). There are significance in terms of positive correlation between acoustic comfort (EAC) and LAeq (R2 = 0.978, P < 0.003) (Fig. 6). Each school for values are generated to mean value of EAC, therefore linear relationship between EAC and LAeq is presented as:

$$EAC = 7.226 - 0.6478L_{Aeq} \quad (8)$$

From the EAC values, it is clear that the School G has highest and School F is lowest. The lowest AEC for School F due to, acoustic comfort depends on room size, windows position and availability of students, length of road either congested or road distance from school building, low density of noise, positioning of road side, and class room size. According to Wen et al. [50], similar observation found and acoustic environment have significant role for education. All school students are separately evaluated through gender aspect, male students (31%) have highly disturbance than the female students (24%) (Fig.S6). The observation is possible due to the fact the adolescent pupils could affected with psychological disturbance during exposure of intense noise, students have more impact during education. Thus, further need to be improve or consider with various cultures, regions, and countries.

4. Conclusions

It may be concluded with a fair degree of accuracy that among the ten studied location, only five locations had lower vehicle density per hour (<1500) namely School D, School A, School C, School F and School J. On the contrary, very high vehicle density per hour (> 4500) was recorded at School H and School B. Present study also demonstrated that the average noise level in and around of roadside schools are well above the standard permissible level.

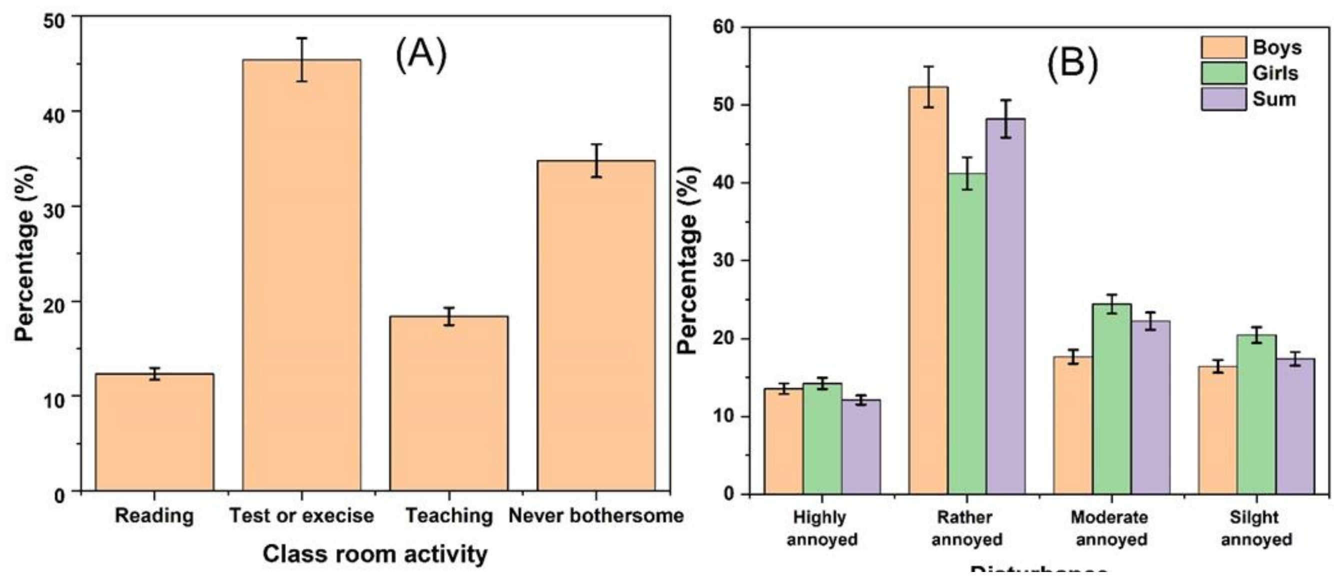

Fig. 5 (A) Impact of noise in various class room basis their activity, (B) Student evaluation of acoustic comfort of their classroom in 10 schools.

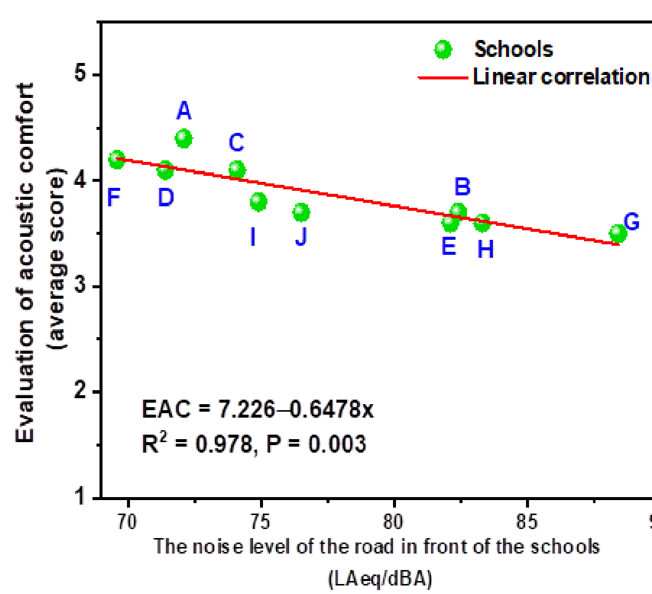

Fig. 6 Correlation analysis of acoustic comfort in various measurement L_{Aeq} values.

From the calculations of the various acoustic descriptors, it is revealed that the inhabitants of all the ten studied locations were under higher health risk. Similarly, noise climate data indicate that early morning and afternoon sessions are the worst among all the studied time intervals in respect of ambient noise. GIS model was also nicely predicted the noise vulnerability in and around the study area. A questionnaire study simultaneously revealed that excessive traffic noise caused irritation as well as sleep disorder. Finally, it is strongly suggested that the inhabitants of areas near the heavy vehicle zones should adopt certain measures to reduce noise intensity through reorientation of bedroom location, window opening habit, use of glass cover in windows etc. There is ample scope for further field and experimental studies to evaluate the gravity of impact of vehicular (heavy and light) noise pollution on community health and academic performance of school children. Further, research will focus on the strategies of reduction of noise level in and around of school building which may ultimately provide more pleasant and peaceful environment.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRedit Author Statement

Soumya Kundu: Conducted experiment, data recording, Mapping, type setting,
Kamalesh Sen: data analysis, graphical presentation,
Naba Kumar Mondal: conceptualization, supervision, original draft-writing.

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