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ORIGINAL ARTICLE

Characterization and Analysis of Ambient Noise Levels in Rohtak City (Haryana)

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ABSTRACT
This paper presents the noise pollution status of Rohtak city with emphasis on objective day - night noise measurement and subjective response of people. Twenty different sites were selected to measure the noise level and determine noise sources at these selected sites. Selected sites fall in the category of residential, commercial, silence zone and road traffic junctions. Noise level measurements and analysis for the locations were based on the noise descriptors L_{Aeq}, L_{10}, L_{90}, L_D, L_N and L_{DN}. The traffic density and PCU during the day and night hours have also been studied at commercial areas and traffic junctions. L_{NP} and TNI have been calculated to Know the noise status at different sites. The results of statistical analysis of sound pressure levels shows that commercial areas have the highest day time noise levels (78 dB(A)) followed by traffic junctions ,residential areas and then by silence zone areas while night time noise levels are maximum on traffic junctions (60.2 dB(A)). This study shows that the major source of noise in Rohtak city is traffic noise. Spectral distributions of noise at different octave band frequencies have also been presented for Sector-1, D- Park, Delhi bypass and Campus school. At 90% confidence level, Mean square ratio (MSR) calculated for L_{NP} is 26.3, while tabulated value is 2.36. Similarly at the same confidence level The MSR calculated for TNI is 25.32 and the tabulated value remains as 2.36. Since in the two cases, the calculated MSR is greater than the tabulated value, there is a significant difference ($p>0.05$) in the noise pollution level and TNI in the locations surveyed based on the data analysed at 90% confidence level. About 44% respondents of questionnaire survey are highly nose sensitive and complained that mainly traffic noise disturb them both in day and night hours. Road map has been prepared for Rohtak city and many solutions have been proposed for noise abatement in the city.
Keywords: Noise pollution level, Passenger Car Units, TNI, Traffic noise, Questionnaire survey.

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INTRODUCTION

In Modern world development in technology, commerce and education has enhanced the urban growth both in developed and developing countries. In the developing countries the process of rapid urbanization has been associated with a low proportion of urban space devoted to roads. Crowded cities and towns, mechanized means of transport, new devices of recreation and entertainment are polluting the atmosphere with their continuous noise. Noise is one of the environmental pollutants that are encountered in daily life. Noise can be defined as any unwanted, disturbing or harmful sound that impairs or interferes with hearing, causing stress, hampers concentration and work efficiency or cause accidents.
According to W.H.O. (World Health Organization) noise pollution is now a day the third most hazardous environmental type of pollution preceding only by air (gas emission) and water pollution. Currently all the developing countries like India are facing threat due to vehicular noise pollution. Migration of people from rural to urban areas, expansion of cities, infrastructure development, population growth and urbanization, are important factors resulting in motorization and consequent increase in levels of various urban pollutions [1]. The total population of India has increased considerably over the past three decades, rising from 846 million in 1991 and 1028 million in 2001 and 1210 million in 2011.
This increase in population coupled with the increase in number of motor vehicles showing alarming levels of traffic congestion, air pollution and noise pollution and road accidents. Urban traffic noise is one of the most critical types of noise and normally considered more interfering than the other types of noises [2]. With the passage of time people has developed the tendency to have personalized modes and need of people also forces increase in number of public vehicles. The annual growth rate of motorized vehicles especially the small vehicles in Rohtak city shows an increasing trend in past ten years (2001-2012) as shown in figure 1 (Regional Transport office, Rohtak).

Human beings are affected in many ways by high noise exposure. These may be socio psychological responses like annoyance and sleep disturbance and physiological effects such as cardiovascular diseases (heart and circulatory problems) and impacts on mental health. In addition traffic noise may also affect children's learning process. Finally prolonged exposure to noise level above 70 dB(A) may lead to irreversible loss of hearing. [3]. High decibel noise causes hearing impairment because of temporary or permanent damage to tiny hair cells of the cochlea of the inner ear. Apart from hearing impairment the electrical conductivity of the skin and the flow of blood are also affected by loud noise. Noise researchers point out that some people quickly adapt to (stop noticing) continuous noise that they often hear, but although noise ceases to be a conscious irritant, its effects on autonomic nervous system continue. These effects do not disappear as people stay longer in the noisy environment.

The first noise survey in the world was carried out in New York City in 1929 [4]. After that numerous noise surveys treating the problem of noise pollution in many cities throughout the world have been conducted [5, 6, 7] and have shown the scale of discomfort that the noise causes in people's lives [8]. As there are a number of studies available on noise pollution from different parts of India but no such study is available for Rohtak city, this present study was undertaken.

STUDY AREA

Rohtak city lies in the south east of Haryana state occupying area of 43.46 sq. km. Rohtak city is geographically located at about $28^0$23'- $29^0$06' N latitude and $76^0$13'- $76^0$58' E longitude with 368737 inhabitants (195478 males and 173259 females). National highway Number 10 (NH-10) passes through this town and it is 70 km from the national capital of India, Delhi. The city is well connected with various towns such as Jhajjar, Sonipat, Gohana, Jind, Bhiwani as well as the national capital Delhi and hence experiences a heavy flow of traffic from these towns. There is a railway junction in the centre of the city connecting the city with Bhiwani, Panipat, Jind and Jhajjar districts and Delhi, the capital of India.

The city population has increased tremendously in last few years and with a boom in economy the vehicular load on roads has also increased many folds. Because of rise in population town has not only expanded horizontally but also vertically. All this has ultimately slowed down the speed of traffic on city roads. Industrial area is very small in the city and that is also outside the city's residential and commercial area, but still it affects the city noise as the raw material and the products are being carried by vehicles plying on the city roads. That's why industries also contribute noise pollution to the city. Thus the vehicular load and mushrooming of settlements along the highways due to increasing population and commercial activities have contributed much to noise pollution in the city.

MATERIAL AND METHODS

Noise level measurements were carried out during summer period (April, May and June 2009). A total of 20 sites (5 Residential areas, 5 Commercial areas, 5 Road Traffic Junctions and 5 Silence zone areas) were chosen for the present study in Rohtak City.

The instrument used for the present study is an integrating type 1 sound level meter (Cesva SC 310) with an octave filter and measuring range between 23-137 dB. All the noise measurements were obtained on working days (Monday to Saturday) and under the suitable meteorological conditions. The instrument was fixed on a stand with the microphone pointed towards the noise source at a distance not less than one meter away from reflecting object. The instrument was calibrated before making measurements.

L_{Ai} (A-weighted instantaneous sound pressure level) measurements were recorded for a period of 4 hour, This procedure was carried out for morning (6:00-11:00 a.m.), afternoon (11:00-4:00 p.m.), evening (4:00-9:00 p.m.) and night-I (9:00p.m.-1:00 a.m.), night-II (1:00-6:00 a.m.) measurement. From these readings commonly used community noise assessment quantities like the A-weighted equivalent sound pressure level (L_{Aeq}), the day time average sound level (L_D), the night time average sound level (L_N), the day-night average sound level (L_{DN}), the noise pollution level (L_{NP}) and the traffic noise index (TNI) were calculated. The statistical indicators L_{10}, L_{50} and L_{90}, which are the sound pressure levels that have been exceeded 10%, 50%, and 90% of the time, were also calculated. To assess the quality of noise at different sites power spectra was taken. For taking the power spectra data, the instrument was set in linear measurement mode.

$$L_{Aeq} = 10 \log_{10} [\frac{1}{N} \sum_{i=1}^{N} (\text{antilog} \frac{L_{Ai}}{10}) n_i]$$

$$L_D = 10 \log_{10} [1/3 (\text{antilog } L_{AeqM}/10 + \text{antilog } L_{AeqA}/10 + \text{antilog } L_{AeqE}/10)]$$

$$L_N = 10 \log_{10} [1/2 (\text{antilog } L_{AeqN\text{-}I}/10 + \text{antilog } L_{AeqN\text{-}II}/10)]$$

$$L_{DN} = 10 \log_{10} [1/24 (15 \text{ x antilog } L_D/10) + (9 \text{ x antilog } L_N+10/10)]$$

$$L_{NP} = L_{Aeq} + (L_{10} - L_{90})$$

$$TNI = L_{90} + 4 (L_{10}-L_{90}) - 30$$

Where (L_{10}-L_{90}) is the noise climate and 30 is the correction factor

Where L_{Ai} is the A-weighted instantaneous sound pressure level reading in decibels. N is the total number of readings, L_{Aeq} is the A-weighted equivalent sound pressure level, L_{AeqM} is the equivalent sound pressure level for the morning measurement i.e. from 6 a.m. to 11 a. m., L_{Aeq} is the equivalent sound level for the afternoon measurement i.e. from 11 a.m. to 4 p.m., L_{AeqE} is the equivalent sound pressure level for the evening measurement i.e. from 4 p.m. to 9 p. m., $L_{Aeq}N_I$ is the equivalent sound pressure level for the time period from 9 p.m. to 1 a.m. and $L_{Aeq}N_{II}$ is the equivalent sound pressure level for 1 a.m. to 6 a.m. L_{10} is the noise level exceeded for 10% of the time, L_{90} is the noise level exceeded for 90% of the time, L_{NP} or noise pollution level and TNI is the Traffic Noise Index. L_D is the day time noise level (0600-2100 hr), L_N is the night time noise level (2100-0600hr), and L_{DN} is the day night noise level i.e. 24 hr noise level. The ambient noise standards set by Central Pollution Control Board (CPCB) for residential, commercial and silence zone areas for day and night hours are given in table -1. Although the standards for traffic junctions are given by World Health Organisation (WHO) are being followed by different researchers in different Indian cities i.e. 70 dB(A) for day time and 65 dB(A) for night hours because there is no defined basic noise levels on Roads prescribed by CPCB [9]. But in case of Rohtak city the junctions are commercial areas and hence the CPCB standards for commercial areas are better applied at these junctions. Road vehicle flow densities at each site were counted simultaneously with the noise level for studying any association between traffic noise level and vehicle flow rate. All types of vehicles plying on the city roads are divided in to six categories for proper computation of the traffic density (TD) and passenger car units (PCU). The PCU equivalents as per Indian road conditions are summarized in table - 2 [10].

RESULTS AND DISCUSSION

Tables 3 to 6 shows the measured and computed values of noise level descriptors in residential, commercial, road traffic junctions and silence zone areas at different selected sites for the morning, afternoon, evening and night periods.

Residential Area

Table-3 shows that noise pollution level L_{NP} ranges from 41.9 dB(A) (Sector-1) to 88.7 dB(A) (Old housing board). Day time L_{Aeq} is minimum at Sector-1 (54.9 dB(A)) and maximum at Hari nagar (73.2 dB(A)) in the residential sites. Night time noise levels also follow the same pattern. Same trend in day night noise level (L_{DN}) is found i.e. minimum in Sector-1 and maximum at Hari nagar. High noise levels in Hari nagar is due to its close proximity to district court, post office, mini secretariat and canal and irrigation department. These places are characterized by high levels of human activities. The streets are very congested in the colony and the hawkers, vendors, light vehicular traffic and small stall owners also occupy some space which consequently hinders traffic movement and also decreases the dissipation of sound. The residential areas having low noise level (sector-1) have lots of open spaces, parks, wide roads in place of narrow streets. Some noise from generator plants, record players and from religious worship centres also disturb the people at their homes. However the major contribution in the residential sites is from the background noise emanating from the vehicles. The day time noise levels (L_D) are above the CPCB limits in all areas except Sector-1. Night time noise levels (L_N) are above the limits in Subhash nagar and Hari nagar and under the limits in other sites.

Commercial Zone

Table-4 depicts the noise level status of five main commercial areas of Rohtak city. Day time noise pollution level (L_{NP}) in commercial centres ranges from 81.2 dB(A) (D-Park) to 91.7 dB(A) (Gohana stand). However night time L_{NP} ranges from 49.7 dB(A) (Kila Road) to 68.1 dB(A) (Sukhpura chowk). The TNI ranges from 37 dB(A) (Gohana Stand, Night-II) to 94.9 dB(A) (Old bus stand, afternoon). L_D ranges from 74.6 dB(A) (Sukhpura chowk) to 78 dB(A) [Old bus stand]. Minimum L_{DN} (day night noise level) found at Sukhpura Chowk and Maximum at Old Bus Stand. The factors responsible for different noise levels at different sites are the location specific in terms of street width, building density and height and other source of intrusive noise. The sources of noise detected are commercial activities, traffic noise from vehicle horns, engines and traffic volume. The environmental sound level measured at a given location is mainly related to road traffic characteristics and especially traffic volume, vehicle horns and tires, unmuffled vehicles, etc. [11]. Urban conditions of a given area also play an important role in influencing the environmental noise levels. Traffic study (Table-9) of the commercial areas shows that Sukhpura chowk occupies the highest PCU and traffic density (TD) and Old bus stand occupies 2nd highest PCU. So the high noise level at old bus stand are mainly due to vehicles and enhanced commercial activities and the multi-storey buildings and narrow roads which cause multiple reflections of sound waves and restrict the dissipation of sound energy. Night time noise is high at Sukhpura chowk as it is on highway and commercial vehicles pass through it at night also while other sites are within the city and city traffic do

not ply at nights and commercial activities also stops at night hours and nearly nil in 2nd half of night period (1a.m. to 6 a.m.). Day time noise level at all the sites are above the recommended values of 65 dB(A). There is variation in the noise levels with period of the day and nature of the location. In general high noise pollutions levels at peak hours of the day i.e. morning (6-11hrs) and Evening (16-21hrs), except at some of the commercial sites where the pattern of noise remains almost same at all day hours. This is because people do their shopping at afternoon hours also. Especially people from rural areas come in the market mid-day hours so that they can be sure of a return transport. Day time noise levels are 9 to 13 dB(A) above the standard limits at all sites while night noise levels are under the limit of 55 dB(A).

Road Traffic Junction

Table-5 depicts the noise level status of selected major Road traffic junctios in Rohtak city. There are so many people who live in urban centres and are exposed to intracity and intercity road traffic noise. Especially the traders, commercial vehicle drivers, traffic wardens and policemen and school children having their schools close to main road have to face the high noise levels harming their health silently. The traffic within a city can be slow (near junction), congested (as in traffic hold ups) or interrupted (by traffic lights or traffic police at a junction) whichever the case, the noise emanating from the traffic is usually high, depending of course, on the traffic volume, magnitude of commercial activities in the area and noise reflecting surfaces (like buildings) in the area as the traffic junctions are mainly commercial hubs. L_{NP} ranges from 59.1 dB(A)(night-II) at Jhajjar Chungi to 88.3 dB(A)(evening) at Hisar Bypass. TNI is maximum at Delhi Bypass (92.7 dB(A) and minimum at Sheela Bypass (49.2 dB(A)). Day time noise level (L_D) is minimum at Delhi Bypass and maximum at Hisar Bypass. Night time noise level (L_N) is minimum at Jhajjar Chungi and maximum at New Bus Stand. Noise patterns are approximately same as the PCU (Passenger car units). Hisar Bypass occupies highest PCU and consequently the highest noise level. Some variations in traffic pattern and noise level are only due to background noise and because of the type of vehicles passing through any junction point like New bus stand where traffic density is not so high but PCU is very high because number of heavy vehicles (buses) is more than other traffic junctions which decrease traffic flow and increase the noise arising from the rest of slow moving traffic. Both the L_D and L_N noise levels are above the limits at all traffic junctions except Jhajjar chungi night noise levels where noise level is near the limits (54.3 dB(A)).

Silence Zone

Table-6 depicts the noise level status of selected silent zone areas in Rohtak city.

Silence Zone is defined as an area up to 100 meter around such premises as hospitals, educational institutions and courts. The Silence Zone is to be declared by the competent authority, Use of Vehicle horns, loudspeakers and bursting of crackers should be banned in these zones. Day time L_{NP} Ranges from 61 dB(A) (Campus school) to 83.6 dB(A) (Civil hospital) and TNI level vary from 42.1 dB(A)(PGIMS, night-II) to 88.3 dB(A)(Civil hospital, morning). L_D is minimum at campus school and highest at Civil hospital. L_{DN} noise levels follow the trend of Day time noise levels i.e. L_D. Here the main Sources of noise are vehicle noise and conversation of people. At silence zone areas morning and evening hours remains the rush hours as these are the opening and closing hours of offices, schools and hospitals and noise is also higher in same time period. That's why everyone have to finish his job (may be patient in hospitals or people in court) in these mean hours. Afternoon noise is higher than evening hours at some sites because people other than the office workers are returning from their destination point (hospital, court and post office) after completing their motive in mid day hours also.

Traffic Density and PCU at Commercial Sites & Traffic Junctions

The noise generated through traffic activities was also assessed by monitoring vehicular population of the city. The vehicular population of the city has increased by about five times during last 10 Years. Since the people in the city prefer an economic comfortable and fast mode of transport, scooters and mopeds and auto rickshaw (three wheelers) have been preferred.

The Category wise distribution of vehicles in Rohtak city from year 2001 to year 2012 in shown in Figure-1.Considering the vehicular population as the major source of noise pollution, measurements were carried out at major traffic junctions of the city and quality of noise also computed using frequency analyser. Hourly count of various types of vehicles gives the traffic density at different timings of the day. The results in terms of Passenger Car Units (PCU) and Traffic Density are summarized in Table-7 and table- 8 for traffic junctions and commercial areas respectively. The PCU System is as per norms being followed in India and the basic consideration behind it is to calculate the traffic flow at a place or the degree of interference that a vehicle offer to other traffic and bring it to a common unit i.e. PCU. The PCU equivalents as per the Indian Practice is Summarized in Table-2.

Power Spectra for different areas of study (Residential, Commercial, Traffic Junction and Silent areas)

In figure 3 sound pressure levels have been plotted against the values of centre frequencies in the octave band (31.5 Hz, 63 Hz, 125 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz and 16 kHz). Study of power spectra in reveals that, in general, noise levels are higher at lower frequencies and decrease with any increase in frequency. However in campus school (silent area) the power spectrum is different in nature. It shows peaks at 500Hz and decrease at other lower and higher frequencies. This may be due to the fact that vehicle noise is main source of noise at places other than campus school however in campus school only a few light vehicles run from the from the road connecting to school and the same road is far from the school building. Only communication noise between children and the birds chirping dominates here.

Statistical Analysis of Noise Pollution Level (L_{NP}) and Traffic Noise Index (TNI)

Fig 4 and 5 shows the variations of mean noise pollution levels (L_{NP}) and TNI of different locations with period of the day which clearly depicts the situation of noise in the city. Study of these figures reveals that in residential areas and at roads junction L_{NP} and TNI rise in morning and evening but descend in afternoon and night to low levels. The high noise pollution levels in morning and evening at these locations can be justified as a result of morning rush hours of office workers, children to school and business men and women, to resume work at offices and open shops for customers. The noise pollution level in afternoon time (11 a.m. to 4 p.m.) at these areas are generally low. This is because the majority of residents are not always available at home in the afternoon. Some are in their offices, markets or shops while children are in their schools or at home after 3 p.m.

To ascertain the significant difference in the noise level exposure in all the sites surveyed throughout the day (from morning to night time), statistical analysis of variance for single factor experiment using F-Distribution was carried out on L_{NP} and TNI. Table 10 and 11 are the analysis of variance table for noise pollution levels (L_{NP} and TNI) respectively. At 90% Confidence level, the mean square ratio calculated for L_{NP} is 26.3, while the tabulated value is 2.36 [12].Similarly at the same confidence level, the MSR calculated for TNI is 25.32.Since in the two cases the MSR is higher than the tabulated value, there is a significant difference ($p < 0.05$) in the noise pollution level and TNI in the location surveyed bases on the data analysed at 90% confidence level.

Annoyance Responses of the people residing or working in the Study area:-

A questionnaire study of people living in different areas shows that approximately 44% people are highly sensitive to noise. While 53% are moderately sensitive towards noise and only 3 % respondents are low noise sensitive. The respondents complained that the noise from traffic, horn blowing, construction noise and noise from loudspeakers (religious places, marriages and other parties) disturb them. People said that sometime it becomes difficult to communicate in market areas felt different about noise from commercial activities and other traffic always near their shops. They respond so because they have become adapted to these noise levels and it has become their habit to talk loudly. Subjects living near to commercial areas (market area) and traffic junctions felt sleep disturbance during night time due to traffic noise. It should be noted that the world Health Organisation recommends a noise level than 35 dB(A) based on the continuous equal energy concept for the restorative process of sleep. Headache and irritability is main health problem felt by people due to high noise.

Road Map of Rohtak City

Fig.6 describes the spatial distribution of noise monitoring sites. They allow an efficient visualization of noise study sites in areas where the land users are sensitive to noise. Noise mapping can be very helpful tool in noise assessment of an urban area. A site map based on day time and night time noise level has been developed. Table 11 gives the brief detail of selected sites as shown in the map in the form of category of studied site and day and night noise level at those selected sites. This map shows that centre of the city and market areas are very much noisy and the residents and shopkeepers tolerate 70-80 dB(A) or more every day. This can cause many health problems for the people in these areas. According to WHO generally 60 dB(A) sounds can result in temporary hearing impairment and 100 dB(A) sounds can cause permanent hearing loss [13].The problem of noise as projected from the present study is similar to those encountered in Nigeria and Delhi (14, 15]. This is the first study in Rohtak city related to noise pollution. From the study it is clear that in most of the areas of city the noise levels exceeded the permissible levels and hence noise reduction measures are required.

Table (1): Noise Standards set by Central Pollution Control Board

Sr.No.	Area	Day (06-21hrs)	Night (21-06hrs)
1	Residential area	55	45
2	Commercial area	65	55
3	Silence zone	50	40
4	Industrial area	75	70

Table (2): PCU Equivalents as per Indian Practice

Sr.No.	Vehicle Type	Equivalents
1.	Passenger car, Tempo, Autorickshaw, Tractor	1.00
2.	Cycle, Motor cycle, Scooter	0.50
3.	Lorry, Bus and Agricultural tractor-trailor unit	3.00
4.	Cycle rickshaw	1.50
5.	Horse- drawn vehicle	4.00
6.	Bullock cart*	8.00

*for smaller bullock carts, a value of 6 will be appropriate

Table (3) : Residential Area Noise Levels

Site	Period of day	L_{Aeq}	L_{10}	L_{90}	TNI	L_{NP}	L_D	L_N	L_{DN}
Sector-1	Morning	55.1	57.5	52.2	43.4	60.4	54.9		54.4
	Afternoon	52.3	55.1	48.3	45.5	59.1			
	Evening	56.4	58.7	50.2	54.2	64.9			
	Night-I	46.1	49.5	42.3	41.1	53.3		43.4	
	Night-II	35.2	36.9	30.2	27	41.9			
Adarsh Nagar	Morning	69.6	71.6	63	67.4	78.2	67.9		66.0
	Afternoon	65.2	68.4	60.2	63.4	73.5			
	Evening	68.5	74.1	61.1	83.1	81.5			
	Night-I	48.1	50.2	43.1	41.5	55.2		45.3	
	Night-II	35.2	37	30.2	27.4	42			
Old Housing Board	Morning	69.6	71.8	52.7	99.1	88.7	69.6		67.6
	Afternoon	66.5	69.5	59.1	70.7	76.9			
	Evening	71.5	72.3	64.5	65.7	79.3			
	Night-I	46.5	47.1	40.5	36.9	53.1		44.4	
	Night-II	40.4	43.2	36.2	34.2	47.4			
Subhash Nagar	Morning	66.1	63.1	50.1	72.1	79	65.9		64.1
	Afternoon	64.1	59.1	47	65.4	76.2			
	Evening	67.2	70.1	52.3	93.5	85			
	Night-I	48.2	54.3	42.1	60.9	60.4		46.2	
	Night-II	42.4	43.9	36.5	36.1	49.8			
Hari Nagar	Morning	73.4	75.3	63.7	80.1	85	73.2		71.2
	Afternoon	69.1	72.2	63.2	69.2	78.1			
	Evening	75.2	78.3	70.1	72.9	83.4			
	Night-I	52.1	55.1	49.1	43.1	58.1		49.3	
	Night-II	42.3	45	34.6	39	50.9			

Table (4): Commercial Areas Noise Levels

Site	Period of day	L_{Aeq}	L_{10}	L_{90}	TNI	L_{NP}	L_D	L_N	L_{DN}
D-Park	Morning	75.7	78.3	68.5	77.7	85.5	75.4		73.5
	Afternoon	73.5	75.2	67.5	68.3	81.2			
	Evening	76.5	78.1	69.2	74.8	85.4			
	Night-I	54.3	56.8	48.5	50.5	62.3		52.2	
	Night-II	48.3	49.9	43.7	38.5	54.5			
Gohana Stand	Morning	77.9	80.5	71.6	77.2	86.8	77.9		75.9
	Afternoon	75.4	78.1	69.5	73.9	84			
	Evening	79.5	82.2	70	88.8	91.7			
	Night-I	55.1	59.2	60.1	65.7	64		52.4	
	Night-II	44.2	46.9	40.2	37	50.9			
Kila Road	Morning	78.4	80.6	69.8	83	89.2	77.9		75.9
	Afternoon	78.6	81.7	69.8	87.4	90.5			
	Evening	76.6	80.6	71	79.4	86.2			
	Night-I	56.2	59.8	50.5	57.7	65.5		53.2	
	Night-II	39.4	43.9	33.6	44.8	49.7			
Old Bus Stand	Morning	79.3	80.3	69.5	82.7	90.1	78		76
	Afternoon	75.1	78.1	62.5	94.9	90.7			
	Evening	78.6	80.6	71	79.4	88.2			
	Night-I	57.5	60.6	50.1	62.1	68		55	
	Night-II	48.7	50.3	42.5	43.7	56.5			
Sukhpura Chowk	Morning	74.2	75.7	65.5	76.3	84.4	74.6		72.9
	Afternoon	72	75.2	60.7	88.7	86.5			
	Evening	76.6	79.1	68.5	80.9	87.2			
	Night-I	57.8	62.5	52.2	63.4	68.1		55.4	
	Night-II	49.9	51.3	43.5	44.7	57.7			

Table (5): Noise at major Road Traffic Junctions

Site	Period of day	L_{Aeq}	L_{10}	L_{90}	TNI	L_{NP}	L_D	L_N	L_{DN}
Delhi Bypass	Morning	70.2	79.2	64.7	92.7	86.7	72.1		70.9
	Afternoon	70.8	73.1	63.5	71.9	80.4			
	Evening	73.1	75.5	65	77	83.6			
	Night-I	60.2	66.3	53.1	58.3	69		57.7	
	Night-II	51.3	54.7	46.5	49.3	59.5			
Sheela Bypass	Morning	73.8	76.3	66.5	75.7	83.6	73.1		71.8
	Afternoon	70	78.5	64.5	90.5	84			
	Evening	74.5	76.5	63.8	84.6	87.2			
	Night-I	59.6	63.2	52.5	65.3	70.3		57.3	
	Night-II	52.4	55.2	47.2	49.2	60.4			
Jhajjar Chungi	Morning	72.2	74.8	62.6	81.4	84.4	72.2		70.6
	Afternoon	70.7	72.5	61.5	75.5	81.7			
	Evening	73.5	76.4	65.7	78.5	84.2			
	Night-I	56.5	59.8	46.1	70.9	70.2		54.3	
	Night-II	50.1	52.3	43.3	49.3	59.1			
New Bus Stand	Morning	77	75.6	64.8	78	87.8	77.4		75.9
	Afternoon	76.5	78.7	68.2	80.2	87			
	Evening	78.5	81.9	69.7	88.5	90.7			
	Night-I	62.7	65.1	65.1	65.1	72.7		60.2	
	Night-II	54.3	57.4	47.2	58	64.5			
Hisar Bypass	Morning	73.4	75.3	63.7	80.1	85	73.5		72
	Afternoon	73.2	75.8	63.6	82.4	85.4			
	Evening	74	76.5	62.2	89.4	88.3			
	Night-I	59.1	68.2	57.5	73.3	69.8		57	
	Night-II	53.2	86.1	48.4	59.2	60.9			

Table (6) : Silence Zone Noise Levels

Site	Period of day	L_{Aeq}	L_{10}	L_{90}	TNI	L_{NP}	L_D	L_N	L_{DN}
Campus School	Morning	51	53.5	42.3	57.1	62.2	50.4		50.3
	Afternoon	49.8	53.8	42.6	57.4	61			
	Evening	50.6	54	43.2	56.4	61.4			
	Night-I	42.2	45.3	36.2	42.6	51.3		40.1	
	Night-II	36.1	37.5	30.2	29.4	43.4			
Model School	Morning	68.8	71.7	60.9	74.1	79.6	67.4		65.6
	Afternoon	67.7	70.3	60.5	68.1	77.1			
	Evening	65.3	68.2	57.8	69.4	75.7			
	Night-I	48.3	50.8	42.5	65.7	56.5		46.9	
	Night-II	45	47.8	39.1	43.9	53.7			
Court complex	Morning	65.1	67.2	54.8	74.4	77.5	63.7		62
	Afternoon	62.5	65.4	55.3	65.7	75.5			
	Evening	63.2	65.6	56.9	62.1	72.1			
	Night-I	47.2	49.5	40.3	47.1	56.4		45.4	
	Night-II	42.3	45.4	36.5	42.1	51.2			
Civil Hospital	Morning	70.2	78.1	64.7	88.3	83.6	71.1		69.2
	Afternoon	68.5	74.5	60.5	86.5	82.5			
	Evening	73.4	75.9	66.2	73	82.6			
	Night-I	48.4	49.8	41.8	43.8	56.4		46.8	
	Night-II	44.5	47.4	39.4	42.6	52.8			
PGIMS (Post Graduate Institute of Medical Sciences)	Morning	67	69.1	61	63.4	75.1	66.1		64.5
	Afternoon	66.5	69.3	60.1	66.9	75.7			
	Evening	64.8	69.1	57.6	74.5	76.6			
	Night-I	50.5	52.4	43.8	48.2	59.1		48.7	
	Night-II	45.8	48.1	40.1	42.1	53.8			

Table (7): Vehicular Traffic data at major Road Traffic Junctions of Rohtak City

Location	Period of day	a) Passenger, Tempo, Tractor	b) Auto rickshaw	Cycle, Motor Cycle, Scooter	Lorry, Bus& Agriculture Tractor, Trailer Unit	Cycle Rickshaw	Small Bullock Cart	PCU	TD
Delhi Bypass	M	520	480	525	475	12	3	2738	2077
	A	712	350	270	400	10	4	2436	1746

	E	530	444	406	590	15	7	2971	1992
	N	20	5	5	25	0	0	103	55
Sheela Bypass	M	660	530	570	304	20		2417	2084
	A	570	380	550	370	15	5	2388	1890
	E	645	590	590	410	12	8	2826	2255
	N	15	4	5	20	0	0	82	44
New Bus Stand	M	360	425	206	598	35	15	2825	1639
	A	320	410	205	610	30	10	2765	1585
	E	410	515	216	490	25	16	2709	1772
	N	5	6	8	30	0	0	105	49
Hissar Bypass	M	460	360	290	830	16	12	3751	1968
	A	415	410	210	560	25	18	3093	1638
	E	470	520	280	720	19	22	3451	2031
	N	7	8	11	25	0	0	129	51
Jhajar Chungi	M	260	206	290	365	25	5	1774	1097
	A	370	190	305	260	15	3	1533	1143
	E	450	210	280	350	10	18	1973	1318
	N	4	5	3	12	0	0	47	24

Note: M= Morning, E= Evening, A= Afternoon, N= Night

Tabl (9) : Vehicular Traffic data at major Commercial Areas of Rohtak City

Location	Period of day	a) Passenger, Tempo, Tractor	b) Auto rickshaw	Cycle, Motor Cycle, Scooter	Lorry, Bus& Agriculture Tractor, Trailer Unit	Cycle Rickshaw	Small Bullock Cart	PCU	TD
D-Park	M	600	760	710	10	20	7	1817	2107
	A	590	790	580	22	15	5	1389	2002
	E	710	820	620	20	20	10	1990	2200
	N	5	7	3	0	0	0	14	15
Ghona Stand	M	330	960	620	16	20	2	1690	1948
	A	350	950	520	16	30	3	1671	1669
	E	3750	970	640	12	35	5	1784	2037
	N	2	1	3	1	0	0	8	7
Kila Road	M	290	820	1040	15	20	7	1753	2193
	A	310	720	720	10	15	2	1455	1777
	E	380	910	970	17	25	6	1900	2308
	N	2	2	2	0	0	0	5	6
Old Bus Stand	M	504	840	520	98	20	20	2048	2002
	A	360	444	450	80	25	25	1457	1384
	E	465	720	490	90	20	20	1850	1805
	N	9	3	5	24	0	0	86.5	41

Shukhpura Chowk	M	656	640	365	580	10	3	3252	2254
	A	413	450	300	404	5	4	2257	1576
	E	676	520	440	400	10	6	2667	2052
	N	8	4	3	27	0	0	95	42

Note: M= Morning, E= Evening, A= Afternoon, N= Night

Table (10) : Analysis of variance for Noise Pollution Level (L_{NP})

Source of variation	SS	DF	MS	MSR
Between Groups	2864.168	3	954.7	26.3
Within Groups	582.314	16	36.3	
Total	3446.482	19		

SS sum of squares, *DF* degree of freedom, *MS* mean square

Table (11): Analysis of variance for Traffic Noise Index (TNI)

Source of variation	SS	DF	MS	MSR
Between Groups	4003.76	3	1334.5	25.32
Within Groups	843.4855	16	52.7	
Total	4847.2455	19		

SS sum of squares, *DF* degree of freedom, *MS* mean square

Table(12). The details of noise monitoring sites as located in Road Map

Site no.	Site name	Category	L_D	L_N
1	Sector-1	Residential	54.9	43.4
2	Adarsh Nagar	Residential	67.9	45.3
3	Old Housing Board	Residential	69.6	44.4
4	Subhash Nagar	Residential	65.9	46.2
5	Hari nagar	Residential	73.2	49.3
6	D-Park	Commercial	75.4	52.2
7	Gohana Stand	Commercial	77.9	52.4
8	Kila Road	Commercial	77.9	53.2
9	Old Bus Stand	Commercial	78	55
10	Sukhpura Chowk	Commercial	74.6	55.4
11	Delhi Bypass	Traffic Junction	72.1	57.7
12	Sheela Bypass	Traffic Junction	73.1	57.3
13	Jhajjar Chungi	Traffic Junction	72.2	54.3
14	New Bus Stand	Traffic Junction	77.4	60.2
15	Hisar Bypass	Traffic Junction	73.5	57
16	Campus School	Silence zone	50.4	40.1
17	Model School	Silence zone	67.4	46.9
18	Court Complex	Silence zone	63.7	45.4
19	Civil Hospital	Silence zone	71.1	46.8
20	PGIMS	Silence zone	66.1	48.7

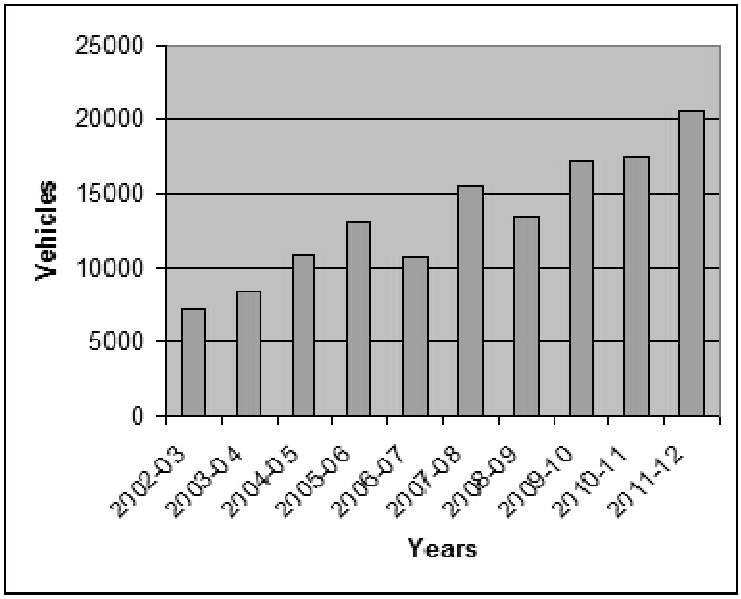

Figure (1): Year wise registered vehicles in Rohtak

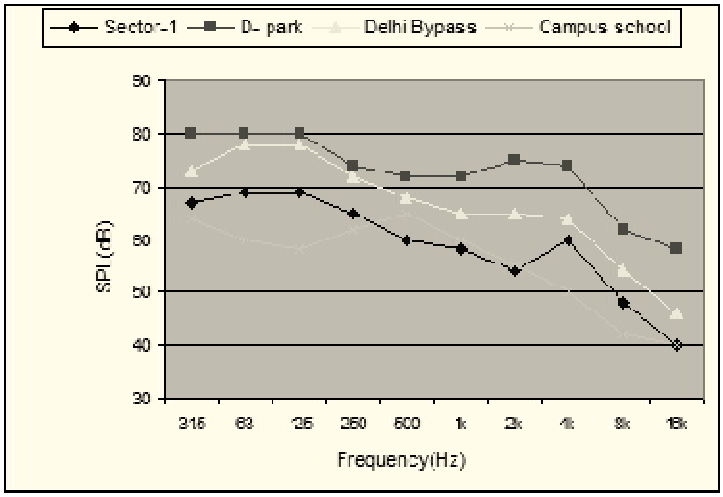

Figure (3): Power spectra in residential (Sector-1), commercial (D- park), traffic junction (Delhi bypass) and silent areas (Campus school)

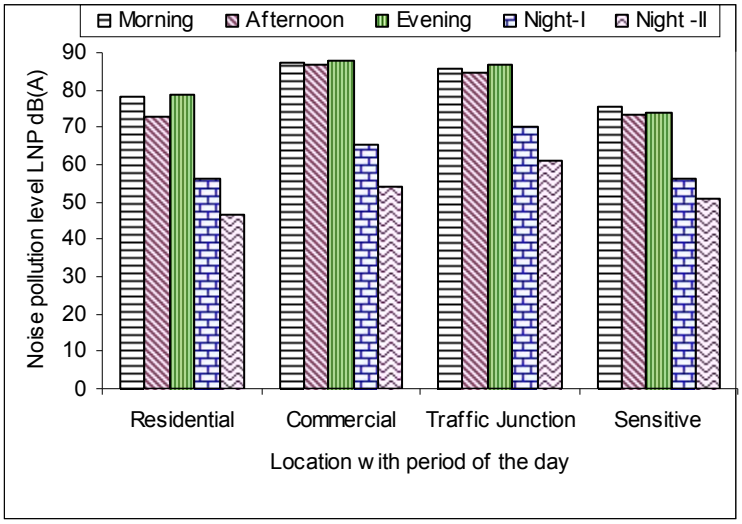

Figure (4): Variation of noise pollution level (L_{NP}) with location and period of the day

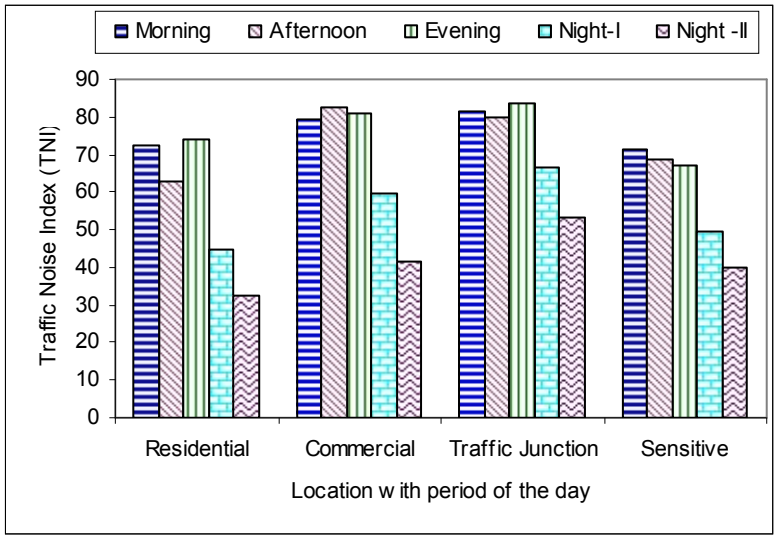

Figure (5): Variation of traffic Noise Index (TNI) with location and period of the day

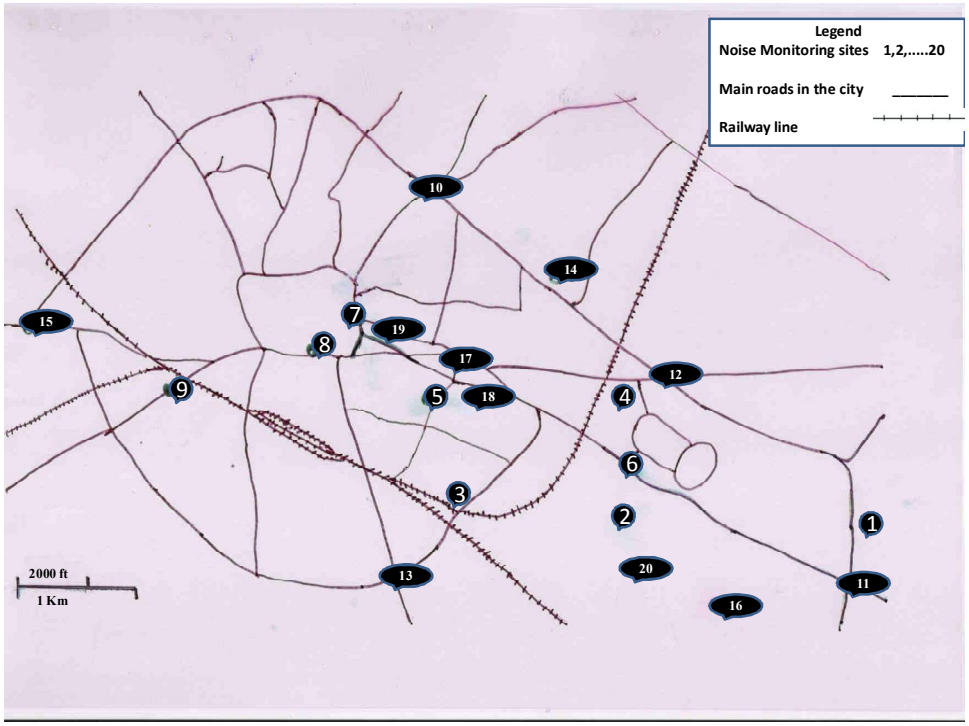

Figure (6): Rohtak city road and railway line map showing noise monitoring sites

CONCLUSION

This study was carried out to evaluate the noise pollution levels in urban areas of Rohtak City. The main selected areas were: Commercial sites, road junction/traffic junctions, Residential areas & Silence Zone areas. The overall investigation reveals that day time noise levels exceeds the CPCB standards of noise at all the measurement points except in Sector-1 (Residential) and night time noise levels mainly exceeds the limits set by CPCB at traffic junctions and Silence Zone areas except at Campus school (Silence Zone). Amongst all the sites selected Hari Nagar is the most noisiest residential site with L_{DN} as 71.2 dB(A), Gohana stand, Kila road and Old bus stand are the noisiest commercial areas with L_{DN} of 76 dB(A) approximately. Highest traffic noise in terms of L_{DN} is at New Bus Stand from where buses come and go whole of the day and night. Civil Hospital is noisiest silence area with 64.5 dB(A) as an L_{DN} value. Hence the present status of noise pollution in Rohtak city poses a severe health risk to the residents which may reduce the productivity directly or indirectly both in public and private sectors. Due to these possible adverse effects of noise pollution on populace, a number of noise abatement measures can be taken.

SUGGESTIONS TO REDUCE NOISE

Since transport infrastructure has been recognized as a major source of noise, technical actions on the transport system like change in road profiles, low noise pavement type, effective repairs to the silencers, limitations or restrictions on traffic (type of vehicle, speed, hours of access etc.) and building of acoustic barriers along the sides of heavily travelled highways running through the residential areas. The authorities should pass laws to regulate excess of the sources of high noise levels, other professionals such as town planners, architects and environmental engineers should have the problems of environmental noise pollution in mind when setting new roads, shopping centres, schools, hospitals and both commercial and residential houses in general. Then the most valuable aid is the noise map of a city can be prepared which is a powerful tool to the general public and government (local & national) to devise noise correction measures.

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